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Blade Assessment for Ice Impact (BLASIM)

User's Manual, Version 1.0

E.S. Reddy and G.H. Abumeri
Sverdrup Technology, Inc.
Lewis Research Center Group
Brook Park, Ohio

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BLADE ASSESSMENT FOR ICE IMPACT (BLASIM)

E.S. Reddy and G.H. Abumeri
Sverdrup Technology, Inc.
Lewis Research Center Group
Brook Park, Ohio 44142

SECTION 1.0

BLASIM PROGRAM DESCRIPTION

1.1 Introduction

When aircraft flies through clouds of super-cooled water droplets, ice formation occurs on forward facing structural components. One such components is the engine inlet. With time, the ice accretes on the inlet and eventually sheds due to structural vibrations (Figure 1.1). As a result, blocks of ice traveling at high speed impacts the engine blades rotating at high RPM. This process may cause severe damage to the blade and subsequently to the engine. Hence, it is necessary to assess the damage due to ice impact.

1.2 Analyses Capabilities

BLASIM utilizes a computationally efficient coarse mesh with 55 nodes and 80 triangular plate finite elements. The plate bending element is very similar to the NASTRAN TRIA3 element [1]. Several types of loading are available in the program. The type of loadings are: pressure, temperature, moisture and centrifugal. The analyses types are: local and root ice impact damage, local and root Foreign Object Damage (FOD), static, dynamic, resonance margin calculations, flutter, and fatigue (Figure 1.2). Also, the code can perform these analyses wih consecutive (identical) ice impacts with geometry update after each impact. A general flow diagram of the BLASIM code is given in Figure 1.3. The technical details of the analyses used in the code are discussed in Reference [2].

The code can analyze solid, hollow, superhybrid and composite blades. The solid blade is made up of a single material where as hollow and superhybrid blades are constructed with prescribed composite layup. The composite blade can have a maximum of seven different material layers with twenty five composite plies. The properties of a composite blade can be specified by inputing one of two options: individual ply properties or fiber/matrix combinations. When the second option is selected, BLASIM utilizes ICAN (Integrated Composite ANalyzer [3]) to generate the temperature/moisture dependent ply properties of the composite blade.

Two types of geometry input can be given: NASTRAN type finite element grid or airfoil coordinates. This option increases the flexibility of the program. Also, the input to the code can be generated through an interactive process with varied levels of sophistication, i.e., by selecting one of the built in symmetric airfoils at 4 or more stations, or providing user's own finite element grid of the blade through a file.

1.3 Organization of the Manual

Section 2.0 of this manual describes the input generation and execution of the BLASIM program. It includes input data for ice impact analysis example. Section 3.0 lists several validation cases to demonstrate the use and reliability of the code. The references are given in Section 4.0. An example of ice impact and parametric study results are given in Appendix A. The option to use fiber-matrix properties instead of ply properties is demonstrated in Appendix B.

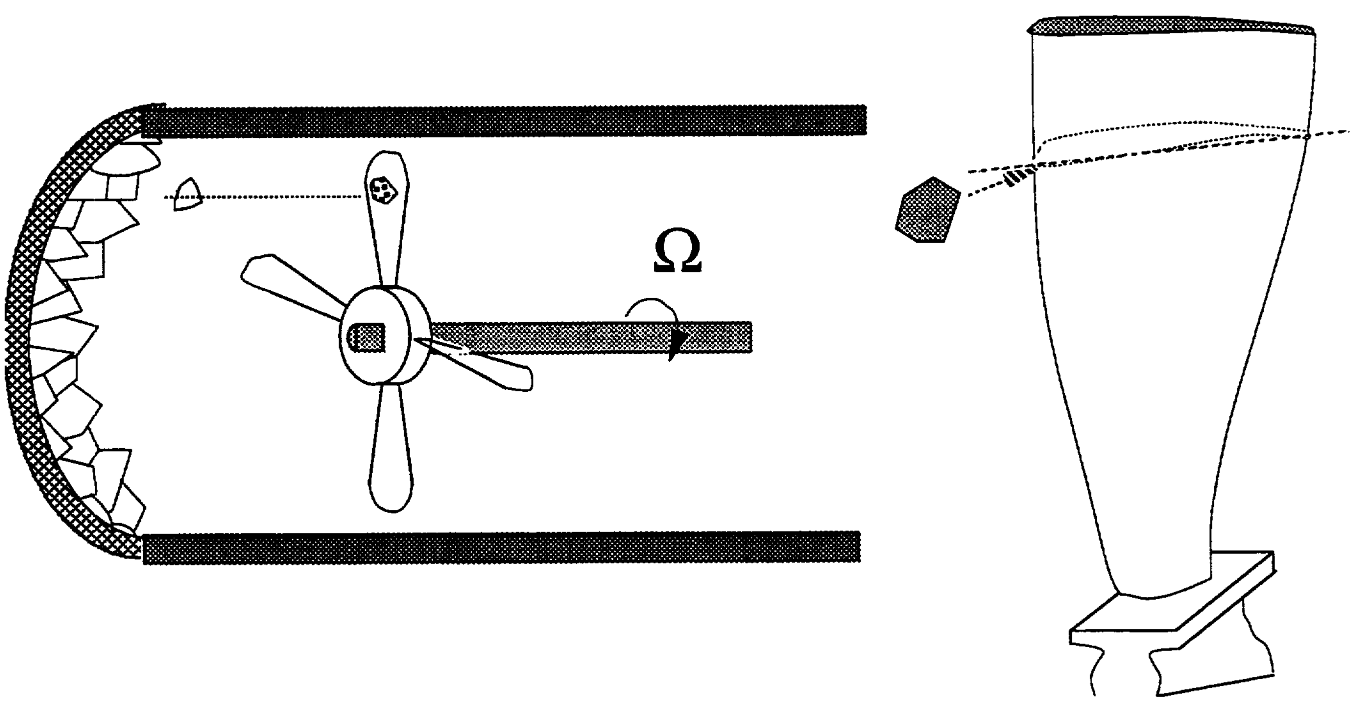


Figure 1.1. A Schematic of Ice Impact on an Engine Blade

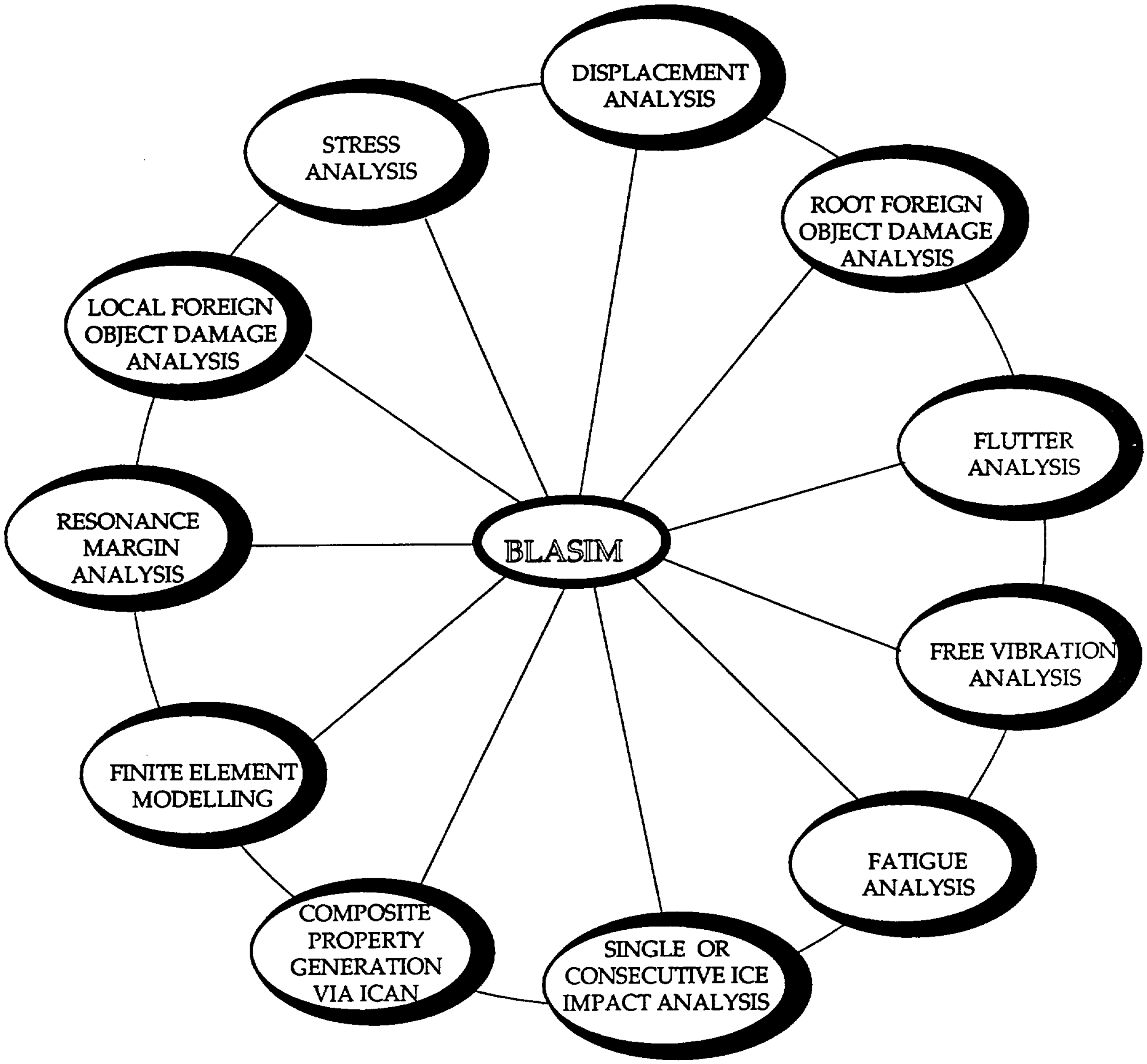


Figure 1.2. Approximate Analysis Modules in the Ice Impact Code

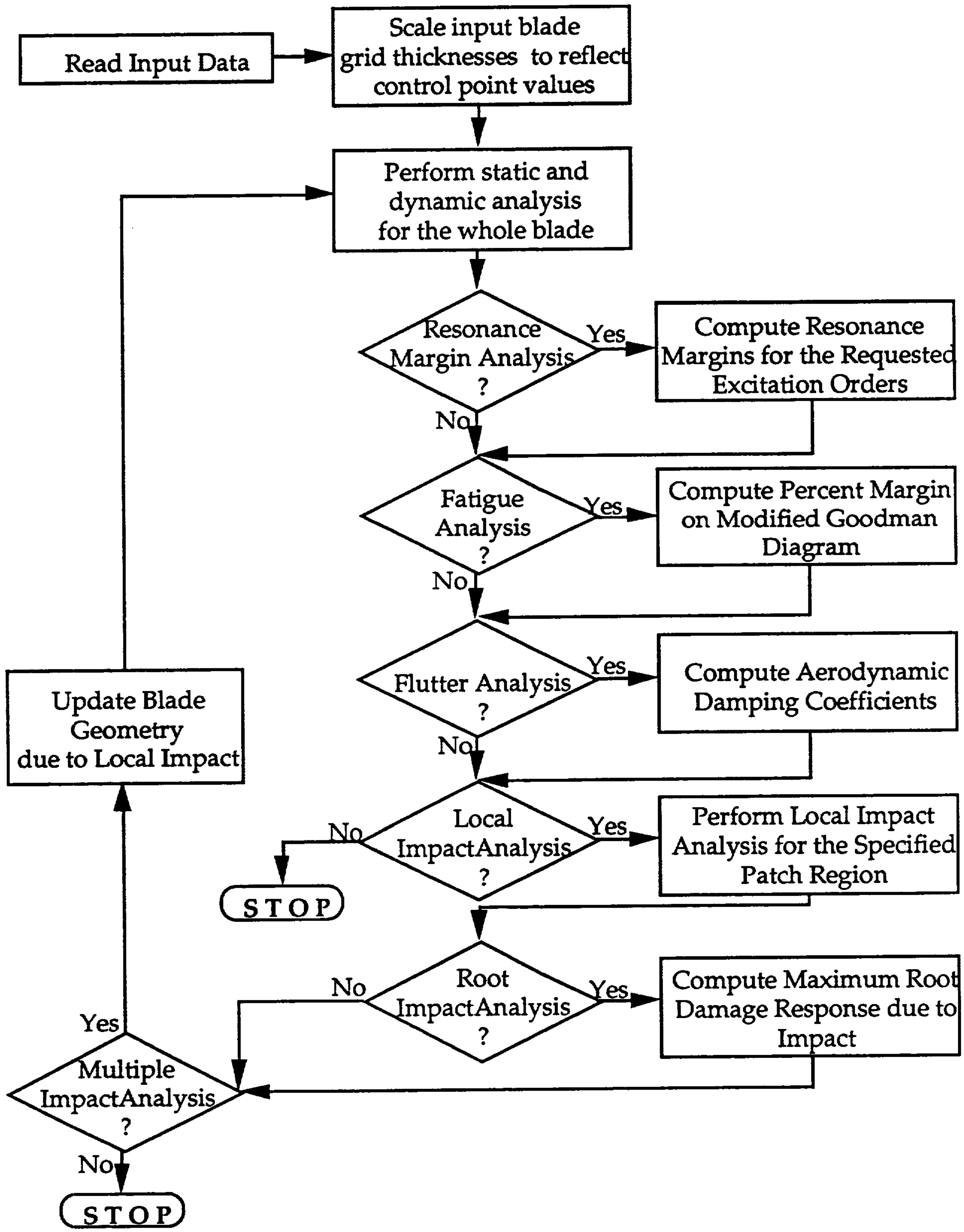


Figure 1.3. General Flow Diagram of the BLASIM Code

SECTION 2.0

INPUT FILE GENERATION AND EXECUTION

2.1 BLASIM Input File Generation

The first step required for using the BLASIM code is to setup an input file. The input and output files needed and generated by the code are shown in Figure 2.1.

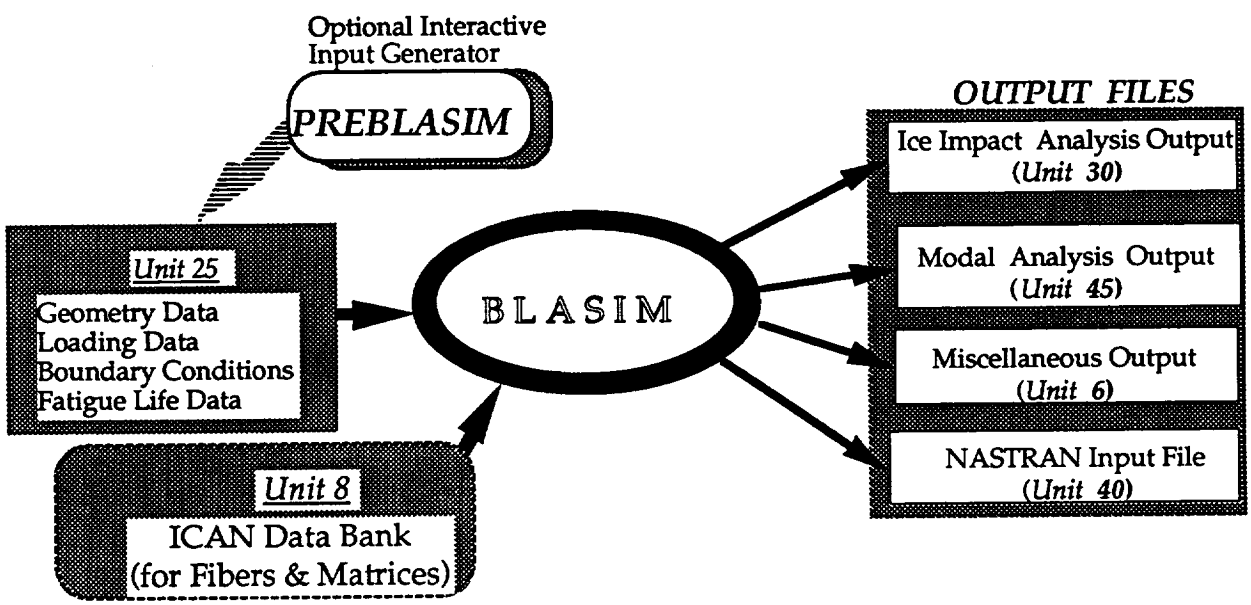


Figure 2.1. Ice Impact Input and Output Files

The input file, *BLASIM.INP,* can be generated either manually or interactively. To construct the data file manually, the format of data blocks described in later sections must be used. Interactive data file generation can be carried out by executing the preprocessor PREBLASIM. The preprocessor is written in FORTRAN and must be compiled and linked as described below depending on the computer system.

System	*Compilation*	*linking*
VAX	*fort preblasim.f*	*link preblasim*
CRAY	*cft77 -dp -ev preblasim.f*	*segldr -o preblasim.exe preblasim.o*
IRIS Workstation	*f77 -c -static preblasim.f*	*f77 -o preblasim.exe preblasim.o*

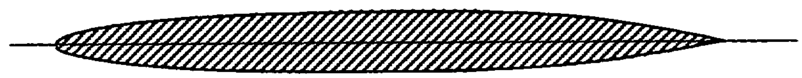
The preprocessor accepts the geometry of the blade in any one of the following three forms:

(a) NASTRAN type finite element grid input file as described in Section 2.3 (CARD A6a).

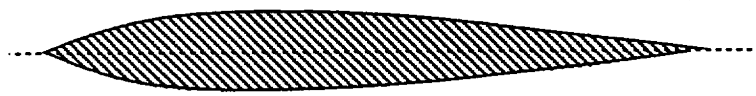
(b) Airfoil coordinates input file as described in Section 2.3 (CARDS A6, A7 and A8).

(c) Construct the blade by selecting one of the three built-in symmetric airfoils [4] in the preprocessor. The maximum thickness of the airfoil is expressed as a percent of the chord length. A minimum of four and a maximum of eleven airfoil stations can be used to describe the blade. These airfoil models are included in the interactive program for demonstration purposes only. The three airfoils built-in into the preprocessor are shown below:

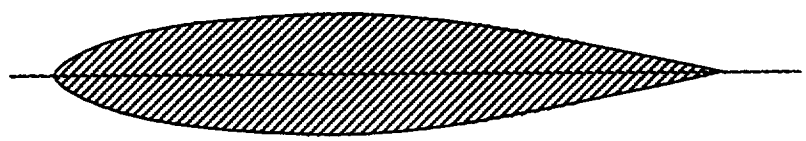
i) NACA 1-series



ii) NACA four-digit



iii) NACA 7-series



To better illustrate the use of this capability, an example is given in this section. The SR-2 blade that is demonstrated here uses option (c) with type (ii) airfoil. Four airfoil input stations are selected as shown in Figure 2.2.

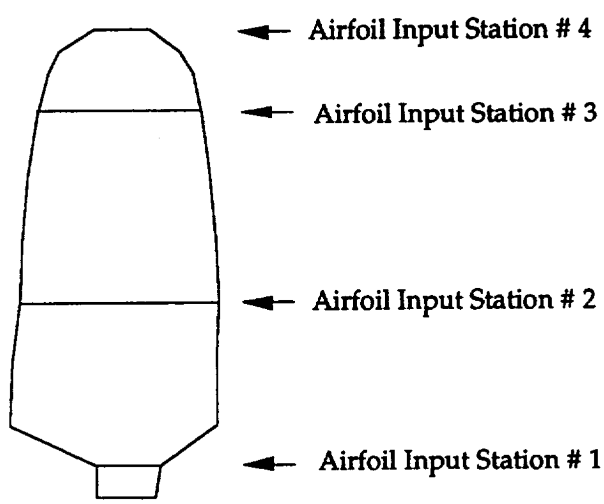


Figure 2.2. Input Blade Details of an Unswept SR-2 Blade

The table below summarizes the data that need to be prepared by the user before running the interactive program which generates the BLASIM input file.

Sl. No.	*Input Variable*	*Value*	*Sl. No.*	*Input Variable*	*Value*
1	Number of blades:	8	24	Station # 4 stagger angle:	40.1°
2	Blade speed :	3000 rpm	25	Ice piece size:	0.65"x0.65"x0.65"
3	Blade root angle :	-35°	26	Ice velocity :	50 knots
4	Broach angle :	0°	27	Impact region lower limit:	0.5
5	Root thickness:	1.08"	28	Impact region upper limit:	0.9
6	Airfoil type selected:	2	29	Redline speed :	3100 rpm
7	Number of airfoil stations:	4	30	Minimum cruise speed :	2900 rpm
8	Dist. to blade attachment:	2.06"	31	Number of excitation orders:	3
9	Station # 1 radius:	2.778"	32	Excitation numbers:	1 2 3
10	Station # 1 chord length:	1.023"	33	Type of blade (solid):	0
11	Station # 1 thickness(% of chord):	15	34	E_{11}:	0.165E+8 psi
12	Station # 1 stagger angle :	3.642°	35	E_{22}:	0.165E+8 psi
13	Station # 2 radius:	6.389"	36	Poisson's ratio V :	0.3
14	Station # 2 chord length:	3.65"	37	G_{12} :	0.634E+7 psi
15	Station # 2thickness(% of chord):	15	38	Density of Titanium:	4.4E-4 $lb.sec^2/in^4$
16	Station # 2 stagger angle :	25.53°	39	Blade cross section offsets :	0.0
17	Station # 3 radius:	10.447"	40	Strength X1T in 1-1 :	74000 psi
18	Station # 3 chord length:	3.35"	41	Strength X1C in 1-1 :	74000 psi
19	Station # 3 thickness(% of chord):	15	42	Strength X2T in 2-2 :	74000 psi
20	Station # 3 stagger angle :	36.44°	43	Strength X2C in 2-2 :	74000 psi
21	Station # 4 radius:	12.25"	44	Shear strength in 1-2:	44000 psi
22	Station # 4 chord length:	1.23"	45	Shear strength in 2-1 :	44000 psi
23	Station # 4 thickness(% of chord):	15	46	# of consecutive impacts	1

The interactive session on a VAX computer screen for the sample SR2 blade discussed earlier is listed here. A new user is advised to run PREBLASIM as the interactive process greatly simplifies the input generation.

```
BBBBBBB    LL          AAAAAA     SSSSSS    IIIIIII  MM     MM
BB    BB   LL         AA    AA   SS           II     MMM   MMM
BB    BB   LL         AA    AA   SS           II     MM MM MM
BBBBBB     LL         AAAAAAAA    SSSSSS      II     MM     MM
BB    BB   LL         AA    AA         SS     II     MM     MM
BB    BB   LL         AA    AA         SS     II     MM     MM
BBBBBBB    LLLLLLLL   AA    AA    SSSSSS    IIIIIII  MM     MM
```

Preprocessor for
BLade ASsessment for Ice iMpact

This Module Will Automatically Generate Input File for BLASIM Program. The Blade Geometry May be Defined in One of the Following Forms: a)Provide the Blade Finite Element Nodal Coordinates and their Thicknesses Thru a File, b)Supply the Airfoil Coordinates Thru a File, c)Select one of the Built-in NACA Airfoils. Any Wrong Entries or Defaulted Data May be Changed by Editing the Input File Created by the Program. To Find the Data Card Number, Variable Name and its Description, See Appendix A of the BLASIM User's Manual.

....hit return to continue....

A Summary of the Information Needed to Run the BLASIM Interactive Program is Given Here:

Description of Entry	CARD #
1. Definition of Blade Geometry, Choices are:	
a. Finite element coordinates & Thicknesses	A6a
b. Airfoil Coordinates & Stagger Angles	A6,A7,A8
c. Construction of Blade With Built-in Airfoil Models	None
2. Number of Blades & Operating Speed	A10,A3
3. Blade Root Angle & Thickness, Broach Angle	A9
4. Option for Local & Root Ice Impact Analysis	B1a,B6b
5. Option for Flutter Analysis	B1a,B3,B4
6. Option for Forcing Function Calculation	B1a
7. Redline & Minimum Cruise Speeds	B5
8. Number of Excitation Orders & Order Number	B5
9. Blade Type & Elastic Material Properties	B1a,B8,B11
10. Pressure Data (Optional)	D2
11. Fatigue Life Data (Optional)	E

....hit return to continue....

Enter Title of the Problem :
sr2 modified titanium blade

The terms in Bold are User's Entries

Blade Description and Analyses Options

```
This is  the First  Section of the Input File.  The Blade Geometry
Speed, and Analyses Options are Defined Here. The User is Expected
to Provide the  Blade  Finite Element Nodal or Airfoil Coordinates
Thru a Data File or Select an Airfoil Model to Construct the Blade.
See the User's Manual For More Details.

   Airfoil or Finite Element Input (A/F)? :a
   Enter Number of Blades, and Blade Speed (rpm):8 3000
   Enter Blade Root Angle (Deg.), Root Thickness, and
   Broach Angle (Deg., See Fig. 7 of User Manual):-35 1.08 0.0

   Three Airfoil Models are Available for Selection to
   Construct the Blade Accordingly. These Airfoil Models
   are Listed Below:

       1. NACA 1-series Airfoil with Maximum Thickness Expressed
          as a Percent of the Chord. The Percentages Allowed are: 6,
          9, 12, 15, 18, and 21. The Commonly Used Section of this
          Family Have Minimum Pressure at 0.6 of the Chord from the
          Leading Edge and Referred to as NACA 16-series section.

       2. NACA Four-Digit Airfoil Model With Maximum Thickness
          Expressed as a Percent of the Chord. The Percentages that
          May be Selected are: 6, 9, 12, 15, 18, 21, and 24.

       3. NACA 7-series With a Basic Thickness of 15%. The Model
          Available Here Has a Minimum Pressure at 0.4 of the Chord
          on Both the Upper and Lower Surfaces.

       Do You Want to Construct Your Blade With Any of the
       Available Airfoil Models? (Enter Yes or No):y


   Select the Airfoil Model Desired
   Enter 1    for NACA 1-series   Airfoil Type
     "   2    for NACA Four-Digit Airfoil Type
     "   3    for NACA 7-series   Airfoil Type:3

   Note: A Minimum of 4 Airfoil Stations are Required to Define
   ----: the Blade. Always, the First Airfoil is the Starting
         Station Number at Which Blade Description Begins.
         The Last Airfoil is for the Tip Station. The Blade
         Attachment is Described Separately.

   Enter No. of Spanwise Input Airfoil Stations :4

   Enter the Distance from the the Engine Center
   to the Blade Attachment :2.06


   Enter Chord Length for Blade Station # 1: 1.023

   Enter the Angle Between Plane of Rotation of Rotor Stage
   and Chord Normal (Degrees) and the Distance From the
   Engine Center Line for Blade Station # 1: 3.642 2.778

   Enter Chord Length for Blade Station # 2: 3.65
```

```
Enter the Angle Between Plane of Rotation of Rotor Stage
and Chord Normal (Degrees) and the Distance From the
Engine Center Line for Blade Station # 2: 25.53 6.389

Enter Chord Length for Blade Station # 3: 3.35

Enter the Angle Between Plane of Rotation of Rotor Stage
and Chord Normal (Degrees) and the Distance From the
Engine Center Line for Blade Station # 3: 36.44 10.447

Enter Chord Length for Blade Station # 4: 1.23

Enter the Angle Between Plane of Rotation of Rotor Stage
and Chord Normal (Degrees) and the Distance From the
Engine Center Line for Blade Station # 4: 40.1 12.25

Do You want to scale the Input Blade Thicknesses
Along the Span (Enter Yes or No):n

Do You Need Local Ice Impact Damage Analysis?
        (Enter Yes or No) :y
Do You Need Root Ice Damage Analysis?
         (Enter Yes or No) :y
Enter Ice Piece Length, Width, and Thickness (inches) :0.65 0.65 0.65
Enter Ice Velocity (knots) :50

Ice Density is Defaulted to 8.42E-05 (lb.sec**2/in**4)
Enter Density Now or Hit Return to Accept Default Value:
Enter Starting and Ending Ice Impact Location
Along the Span as Fractions for Impact Modelling:0.5 0.9

Enter the Number of Consecutive Ice Impacts
(It Includes Geometry Update Following Each Impact): 1

Do You Need Flutter Analysis?
         (Enter Yes or No) :n

Do You Need Resonance Margin Analysis?
         (Enter Yes or No) :y

Do you Need Forcing Function Calculated?
         (Enter Yes or No) :n
Enter Redline and Minimum Cruise Speeds (RPM) :3100 2900
Enter Number of Excitation Orders (max. 5):3
Enter 3 Excitation Order Nos. (1,2,3, etc.) :1 2 3

Enter Code for Type of Blade Construction
(0:solid; 1:hollow; 2:superhybrid; 3:composite :0

Enter E11, E22, Nu12, G12, and Density
 for Solid Blade:16.5e06 16.5e06 0.30 6.34e06 0.000444

Enter Ultimate Strengths (psi): Tension-11,
Compression-11, Tension-22, Compression-22, and
Shear-12  for Solid Blade:74000 74000 74000 74000 44000

The Blade Offsets are defined as..
  x = ACLX*Z + BCLX*Z**2 + CCLX*Z**3
```

```
   y = ACLY*Z + BCLY*Z**2 + CCLY*Z**3
 where Z is spanwise variable
       y is chordwise variable
  and  x is transverse variable

 The Offsets are Defaulted to Zero, to Accept the
 Default Values Hit Return or Enter Now ACLX, BCLX,
 CCLX, ACLY, BCLY, and CCLY:

Pressure Data
-------------

This is the Third Section of the Input File Where Pressure Loading
Data are Defined. If Pressure Loading is Applied, the User Has the
Option of Either Providing Data Thru a  File or Entering a Uniform
Pressure in This Section. Refer to the User's Manual for Details.

Is there Any Pressure Loading (Enter Yes or No):n

Fatigue Life Data
-----------------

This Section of  the Input File is for Fatigue Data.   If Fatigue
Analysis is Desired, then Data  Such as Static and Dynamic  Stress
Limits are Entered Here.  Refer to the User's Manual for Details.

Do You Need to Enter Fatigue life Data for Forcing
Function Calculation? (Enter Yes or No):n

Boundary Conditions Data
------------------------

Boundary  Conditions  Data Are  Defaulted,  i.e.,  All  Degrees of
Freedom at the Blade Root are Restrained.  To Change the Defaulted
Boundary Conditions, Refer to the User Manual, Section 2.0

The Input File Required to Run the BLASIM Code is  Generated
Under the Name BLASIM.INP. Use the Command or Job File Given
in the User's Manual to Run the Code on VAX or CRAY XMP.
```

Following the interactive session, a file named BLASIM.INP is created. This file is the input to the BLASIM code.

Listing of BLASIM.INP

```
sr2 modified titanium blade
AIRFOIL COORDINATES TYPE                                                        CARD A2
 3000.0                                      3.0    300.0                       CARD A3
5                                                                   2.0         CARD A4
  2.060                         3.64                                26          CARD A5
  0.000    0.005    0.008    0.013    0.026    0.051    0.077    0.102    0.153CARD A6
  0.205    0.256    0.307    0.358    0.409    0.460    0.512    0.563    0.614CARD A6
  0.665    0.716    0.767    0.818    0.870    0.921    0.972    1.023         CARD A6
  0.000    0.012    0.015    0.018    0.025    0.035    0.042    0.049    0.058CARD A7
  0.065    0.071    0.074    0.076    0.077    0.075    0.072    0.067    0.062CARD A7
  0.056    0.048    0.040    0.031    0.021    0.012    0.005    0.000         CARD A7
```

```
  0.000  -0.012  -0.015  -0.018  -0.025  -0.035  -0.042  -0.049  -0.058CARD A8
 -0.065  -0.071  -0.074  -0.076  -0.077  -0.075  -0.072  -0.067  -0.062CARD A8
 -0.056  -0.048  -0.040  -0.031  -0.021  -0.012  -0.005   0.000        CARD A8
  2.778                    3.64                           26           CARD A5
  0.000   0.005   0.008   0.013   0.026   0.051   0.077   0.102   0.153CARD A6
  0.205   0.256   0.307   0.358   0.409   0.460   0.512   0.563   0.614CARD A6
  0.665   0.716   0.767   0.818   0.870   0.921   0.972   1.023        CARD A6
  0.000   0.012   0.015   0.018   0.025   0.035   0.042   0.049   0.058CARD A7
  0.065   0.071   0.074   0.076   0.077   0.075   0.072   0.067   0.062CARD A7
  0.056   0.048   0.040   0.031   0.021   0.012   0.005   0.000        CARD A7
  0.000  -0.012  -0.015  -0.018  -0.025  -0.035  -0.042  -0.049  -0.058CARD A8
 -0.065  -0.071  -0.074  -0.076  -0.077  -0.075  -0.072  -0.067  -0.062CARD A8
 -0.056  -0.048  -0.040  -0.031  -0.021  -0.012  -0.005   0.000        CARD A8
  6.389                   25.53                           26           CARD A5
  0.000   0.018   0.027   0.046   0.091   0.183   0.274   0.365   0.548CARD A6
  0.730   0.913   1.095   1.278   1.460   1.643   1.825   2.008   2.190CARD A6
  2.372   2.555   2.738   2.920   3.103   3.285   3.467   3.650        CARD A6
  0.000   0.044   0.052   0.066   0.090   0.125   0.151   0.173   0.207CARD A7
  0.233   0.252   0.265   0.272   0.274   0.267   0.256   0.240   0.221CARD A7
  0.199   0.173   0.143   0.110   0.076   0.044   0.016   0.000        CARD A7
  0.000  -0.044  -0.052  -0.066  -0.090  -0.125  -0.151  -0.173  -0.207CARD A8
 -0.233  -0.252  -0.265  -0.272  -0.274  -0.267  -0.256  -0.240  -0.221CARD A8
 -0.199  -0.173  -0.143  -0.110  -0.076  -0.044  -0.016   0.000        CARD A8
 10.447                   36.44                           26           CARD A5
  0.000   0.017   0.025   0.042   0.084   0.168   0.251   0.335   0.502CARD A6
  0.670   0.837   1.005   1.172   1.340   1.507   1.675   1.842   2.010CARD A6
  2.177   2.345   2.513   2.680   2.848   3.015   3.182   3.350        CARD A6
  0.000   0.040   0.048   0.060   0.082   0.115   0.139   0.159   0.190CARD A7
  0.214   0.231   0.243   0.250   0.251   0.245   0.235   0.221   0.203CARD A7
  0.183   0.159   0.131   0.101   0.070   0.040   0.015   0.000        CARD A7
  0.000  -0.040  -0.048  -0.060  -0.082  -0.115  -0.139  -0.159  -0.190CARD A8
 -0.214  -0.231  -0.243  -0.250  -0.251  -0.245  -0.235  -0.221  -0.203CARD A8
 -0.183  -0.159  -0.131  -0.101  -0.070  -0.040  -0.015   0.000        CARD A8
 12.250                   40.10                           26           CARD A5
  0.000   0.006   0.009   0.015   0.031   0.062   0.092   0.123   0.185CARD A6
  0.246   0.308   0.369   0.431   0.492   0.553   0.615   0.677   0.738CARD A6
  0.799   0.861   0.923   0.984   1.046   1.107   1.168   1.230        CARD A6
  0.000   0.015   0.018   0.022   0.030   0.042   0.051   0.058   0.070CARD A7
  0.079   0.085   0.089   0.092   0.092   0.090   0.086   0.081   0.075CARD A7
  0.067   0.058   0.048   0.037   0.026   0.015   0.005   0.000        CARD A7
  0.000  -0.015  -0.018  -0.022  -0.030  -0.042  -0.051  -0.058  -0.070CARD A8
 -0.079  -0.085  -0.089  -0.092  -0.092  -0.090  -0.086  -0.081  -0.075CARD A8
 -0.067  -0.058  -0.048  -0.037  -0.026  -0.015  -0.005   0.000        CARD A8
          -35.0   1.080   2.778     0.0                                CARD A9
                                                     8.0               CARD A10
   2    0    5    0    1    1    0    0    1   1.02300    1           CARD B1a
.0001.0001.0001.0001.0001.000                                          CARD B1b
2  0.1535 5  0.1845                                                    CARD B2
 3100.000  2900.000     3    1     2    3                              CARD B5
  0.65000   0.65000   0.65000  50.00000  0.000084   0.00001   0.00000  CARD B6b
  0.50000   0.90000   16   40         1                                CARD B7
0.165E+08 0.165E+08   0.30000 0.634E+07   0.00044                      CARD B8
 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000                        CARD B9e
0.740E+05 0.740E+05 0.740E+05 0.740E+05 0.440E+05 0.440E+05            CARD B11
```

A small section of the output written to FORTRAN logical unit 30 (see Figure 2.1) is shown below:

```
** * * * *  Tip Displacements  * * * * *

  Max Tip Extension   0.0063

  Max In Plane Displ  0.6615  0.3303


* * * * Resonance Margin Information * * * *


Frequencies At  3000.0 rpm      69.49    227.33    244.48
Frequencies At  3300.0 rpm      75.14    231.24    245.13

Red Line Speed-rpm =  3100.0   Min Cruise Speed-rpm =  2900.0


* * * * Ice Impact Input and Derived Parameters * * * *

Blade velocity at impact radius .....      2644.50 in/sec
Ice velocity ........................      1012.69 in/sec    (  50.00 knots)
Ice equivalent radius ...............         0.40 inch
Local impact reference node .........       16
Global corresponding impact node ....       11
Impact radius at reference node .....         8.42 inch
Impact angle ........................         9.79 degrees
Stagger angle .......................        30.75 degrees
Density .............................     0.840E-04 lbm.sec^2/in^4


* * * * Local Ice Impact Output * * * *

Maximum Leading Edge Strain % .........  0.96368E-04
Time Of Occurence .....................  0.19000E-03
```

2.2 Running the BLASIM Code

The BLASIM code can be run on the VAX, CRAY XMP and IRIS workstation. The procedure required in order to use the BLASIM code on these systems is given in this section.

2.2.1 <u>How to Run BLASIM on VAX</u>

The first step is to compile and link the BLASIM program to create an executable named BLASIM.EXE. The following commands are issued interactively:

```
$ FORT  BLASIM        (Compilation command)
$ LINK  BLASIM        (Linking command)
```

A command file named *BLASIM.COM* that can be used to run the BLASIM code is listed below:

```
$ ASSIGN BLASIM.INP     FOR025
$ ASSIGN BLASIM.OUT     FOR030
$ ASSIGN   MISCL.OUT  FOR006
$ RUN  BLASIM.EXE
$ DEASSIGN  FOR006
$ DEASSIGN  FOR025
$ DEASSIGN  FOR026
$ DEASSIGN  FOR030
$ EXIT
```

The following command is issued to execute the code in the batch mode:

```
$ SUBMIT  BLASIM.COM
```

When the execution of the program is completed, the output files, as named in the command file, can be reviewed by the user.

2.2.2 How to Run BLASIM on CRAY XMP

The procedure used here is very similar to the one described in section 2.2.1. The difference here is that a job file named BLASIM.JOB is required to be submitted from a front end computer system such as VAX (to CRAY). The listing of *BLASIM.JOB* is given below:

```
#  USER=myuserid  PW=myuserpwd   (Define userid and user password)
#  QSUB-r  BLASIM                (Define the job file name)
#  QSUB  -nr
#  QSUB  -nc
#  QSUB-q  batch
#  QSUB-lT  30                   (Specify the amount of CPU allowed)
#  QSUB-lM  2.0Mw                (Specify the amount of memory required)
#  QSUB-eo
set  -vxk
cd
mkdir  impact                    (Creates a directory called 'impact')
cd  impact                       (Go to the directory impact is available)
ja                               (Start collecting job statistics)
fetch blasim.f   -t'blasim.for' (Fetch BLASIM FORTRAN source code to CRAY)
cft77 -dp -ev blasim.f         (Compile BLASIM to create an object file)
segldr -o blasim.exe blasim.o  (Link BLASIM to create BLASIM.EXE)
fetch fort.25 -t'blasim.inp'   (Fetch BLASIM.INP after preparing it)
blasim.exe > miscl.out         (Activate the execution of the code)
dispose fort.30 -t'blasim.out' (Dispose the ice impact information file)
ja -s                            (print job statistics)
exit
```

Note that the contents in the parenthesis describe the various commands in the job file. The compilation and linking of the BLASIM code is required only the first time the code is used. Afterwards the executable file '*BLASIM.EXE* ' can be used every time an analysis run is desired.

2.2.3 How to Run BLASIM on IRIS Workstation

The commands on IRIS workstation are similar to CRAY and are given below.

```
f77 -c -static blasim.f        (Compile BLASIM to create an object file)
f77 -o blasim.exe blasim.o     (Link BLASIM to create BLASIM.EXE)
cp blasim.inp fort.25          (copy BLASIM.INP to FORTRAN unit 25)
blasim.exe > miscl.out         (Activate the execution of the code)
```

2.3 Description of Input File

Due to the modular construction of the BLASIM program, data of the input file has been broken down into five separate data blocks: 1) geometry and analysis data, 2) approximate model input, 3) boundary conditions data, 4) pressure data, and 5) fatigue life data. The pressure data are needed only if there is a pressure loading. Also, the fatigue life data are required in the input file if fatigue analysis is to be performed. The boundary conditions of the blade are defaulted by restraining all degrees of freedom at the root, and they are needed in the input file only if the user decides to modify these conditions. All the types of data discussed above can be included in *BLASIM.INP* either by using the interactive program PREBLASIM or manually. The format and the contents of various data blocks are described below.

2.3.1 DATA BLOCK A: Geometry and Analysis Data

This block contains airfoil coordinate data and other airfoil information, analysis speed, etc.

CARD A1

Contents: Title

1	2	3	4	5	6	7
			ITTLE			

70

```
SR-2 UNSWEPT BLADE EXAMPLE
```

Field	Item	Format	Description
1-7	ITTLE	A	Descriptive title.

CARD A2

Contents: Geometry Input Mode

1
COORT
7
NASTRAN

Field	Item	Format	Description
1	COORT	A7	This option specifies the type of geometry desired by the user. Enter: 'NASTRAN' for NASTRAN type geometry or 'AIRFOIL' for airfoil coordinates.

CARD A3

Contents: RPM, No. of Frequencies and RPM Increment

1	2	3	4	5	6
RPM				ROOT	DRPM
8			32	40	48
4000.0				3.0	400.0

Field	Item	Format	Description
1	RPM	F	Analysis speed, RPM. This is the speed desired for flutter stability evaluation.
5	ROOT	F	Number of frequencies desired, maximum of 5.
6	DRPM	F	Delta RPM. This RPM increment is added to the input RPM and another frequency is calculated at the higher speed for the purpose of computing the sensitivity of the natural frequencies to speed. 1000.0 is suggested.

CARD A4

Contents: Blade Station Definition

1	2	3	4	5	6	7	8
NSTA							BRS
2						54	62
11							2.0

Field	Item	Format	Description
1	NSTA	I	Number of spanwise coordinate input stations for blade geometry input description, a maximum of 11 stations can be used.
2	BRS	F	Starting station number at which blade description begins.

CARD A5 (Required if Airfoil Coordinates are used on Card A2)

Contents: Blade Station Radius, Chord Angle, Coordinate Instruction. Input Cards A6, A7 and A7 for Each Blade Station.

1	2	3	4	5	6	7	8	9	10
R				ALPHA					NO
8			26	32				57	61
2.6				3.64					9

Field	Item	Format	Description
1	R	F	Distance from the engine center line to the blade station, inches. The first input station should be the blade attachment, the last the tip station. (Figure 2.6)
5	ALPHA	F	Angle between plane of rotation of rotor stage and chord normal (y=0), degrees. (Figure 2.3)
10	NO	F	The number of coordinate stations along the chord used to describe the airfoil profile. Maximum of 53 points. 30-50 are recommended.

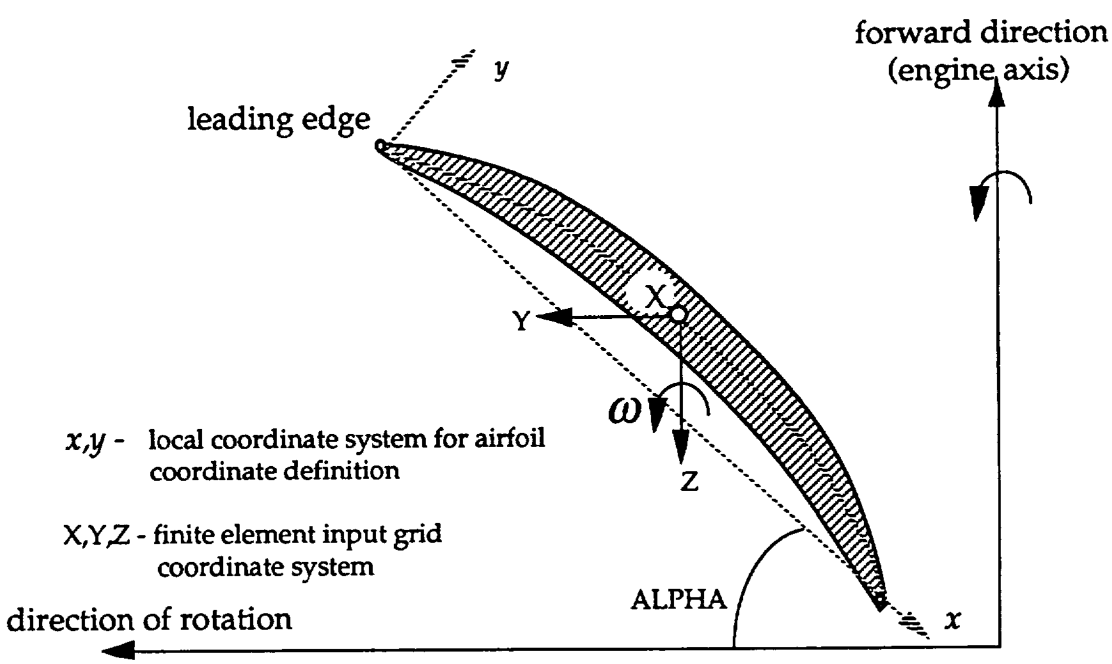


Figure 2.3. Definition of Angle ALPHA

CARDS A6, A7, AND A8 (Required if Airfoil Option is Input on Card A2)

Contents: Airfoil Coordinates

These cards follow Cards A5 at each station. Input x values first, then upper y's, then lower y's (Figure 2.4). For a solid or hollow airfoil with a conventional parallelogram neck geometry to serve as the transition between airfoil root and dovetail attachment, the coordinates of the first station will be ignored. The coordinates for station 1 must be input, however, usually using the station 2 coordinates. BLASIM will build a model of the neck, shown in Figure 2.5, from information included on Card A9. For an airfoil with no platform and a contoured neck, such as the superhybrid blade, the neck is treated as an extension of the airfoil, and thus proper section 1 coordinates are required.

When using the interactive program PREBLASIM which generates BLASIM.INP automatically, the user must prepare the airfoil coordinates in a separate file with a format as indicated below in this card description. If the airfoil generator option in PREBLASIM is used, then the user will not be required to provide this airfoil coordinate file.

	1	2	3	4	5	6	7	8	9
A6:	X(1)	X(2)	X(3)	...					
	8	16	24	32	40	48	56	64	72

	1	2	3	4	5	6	7	8	9
A7:	YU(1)	YU(2)	YU(3)	...					
	8	16	24	32	40	48	56	64	72

	1	2	3	4	5	6	7	8	9
A8:	YL(1)	YL(2)	YL(3)	...					
	8	16	24	32	40	48	56	64	72

0.000	0.128	0.256	0.384	0.512	0.639	0.767	0.895	1.023
0.000	0.103	0.122	0.120	0.108	0.089	0.065	0.036	0.000
0.000	-0.103	-0.122	-0.120	-0.108	-0.089	-0.065	-0.036	0.000

Field	Item	Format	Description
9 values per card. Fields of 8.	X	F	The x coordinates of the blade cross section given in ascending order for NO points in inches (Figure 2.4).

Start each set on a card. YU	F	The upper y coordinates of the blade cross section corresponding to the x coordinates in inches (Figure 2.4).
YL	F	The lower y coordinates of the blade cross section corresponding to the x coordinates in inches (Figure 2.4).

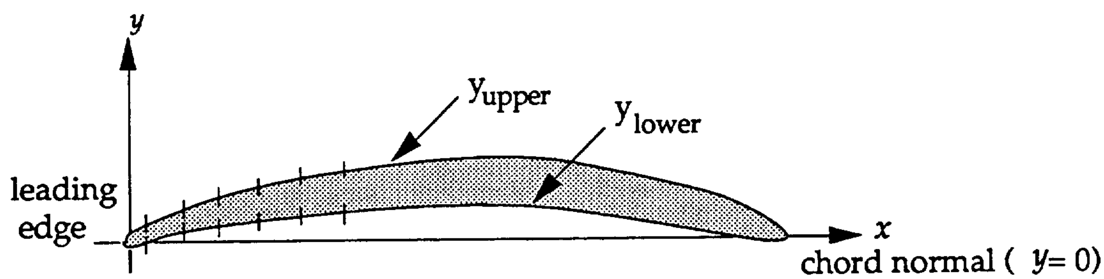


Figure 2.4. 1x2y Airfoil Section Coordinate Input

CARDS A6a, A7a, A8a (Required if NASTRAN Type Geometry is Used, Card A2)

Contents: NASTRAN Blade Geometry Description

This card replaces card A6, A7, and A8. Unlike NASTRAN, BLASIM ignores the mnemonic and assumes that 55 grid cards will follow. Standard NASTRAN format is used.

CARD A6a

When the NASTRAN type coordinates option is selected, the user must prepare an input file with format as indicated below.

1	2	3	4	5	6	7
GRID	N		XN	YN	ZN	THCK
8	16	24	32	40	48	56
GRID	1		2.0600	0.0000	-0.4710	0.7267

Field	Item	Format	Description
1	GRID	A8	not used
2	N	I8	Grid point ID
4 - 6	XGRID(I,J,K)	3F8.5	Grid point coordinates
7	THCK	F8.5	Grid point thickness

Notes:

1. The NASTRAN model used in BLASIM consists of 80 triangular elements. The element connectivity is generated automatically in the code (Figure 2.5).
2. If the interactive input generator PREBLASIM is usedto construct the input file *BLASIM.INP*, the NASTRAN grid cards (coordinates) must be made available through a file with a known format (see example in Appendix A).

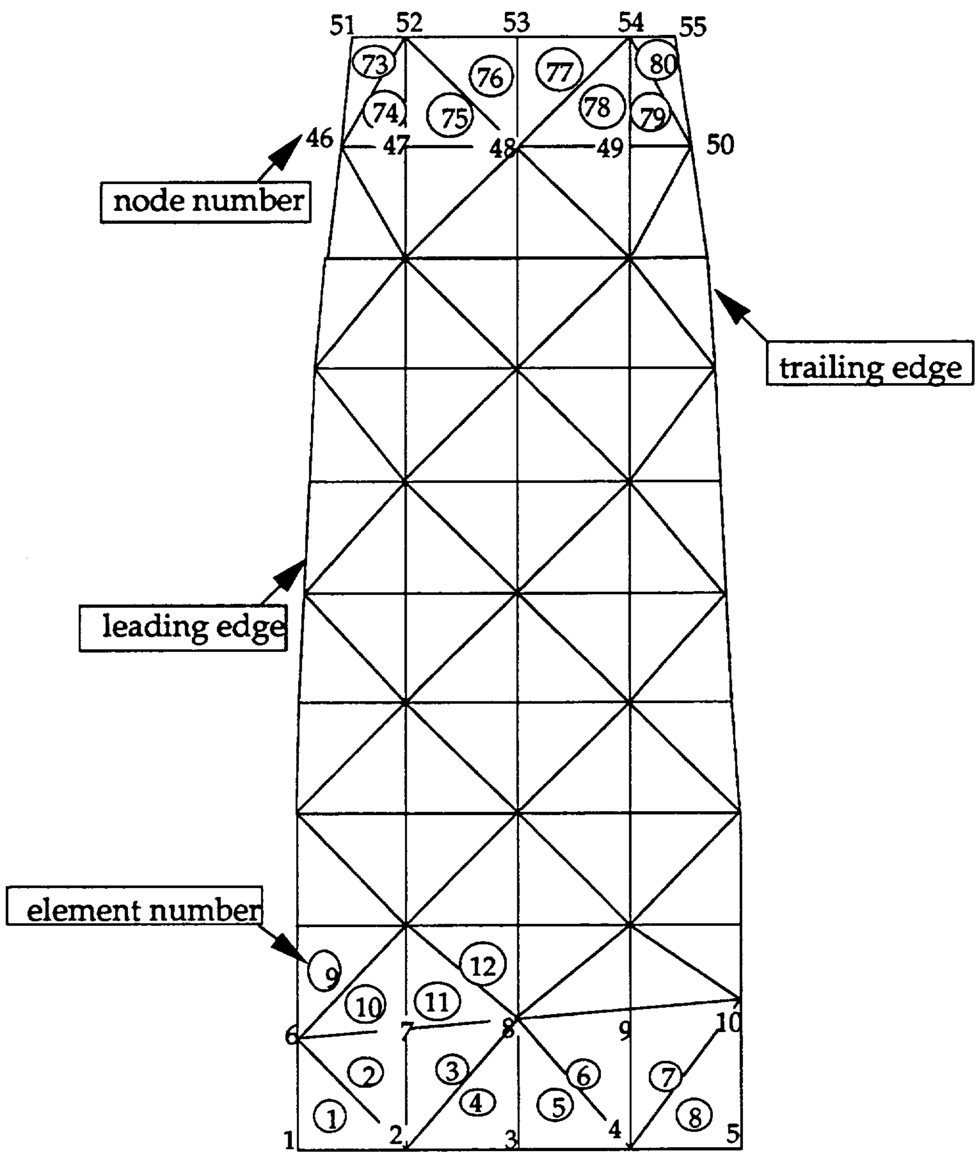


Figure 2.5. Finite Element Mesh of the Blade Model

CARD A9

Contents: Blade Root Angle. Neck Description.
Card is required but ignored if NASTRAN type geometry is used on Card A2.

1	2	3	4	5
	THER	TROOT	RROOT	BRANG
8	16	24	32	40
	15.0	1.08	2.778	0.0

Field	Item	Format	Description
1	THER	F	Blade root angle, degrees. This is the angle between the blade platform and the engine center line. Positive counterclockwise.
2	TROOT	F	Thickness of blade neck, inches.
3	RROOT	F	Radius of first airfoil station, inches. This radius is the radius at the half-chord point of the airfoil root. RROOT does not have to correspond to an airfoil 1X2Y coordinate input station radius, but must lie between R(1) and R(NSTA).
4	BRANG	F	Broach angle, the angle between the center line of the broach slot and an axial plane, degrees.

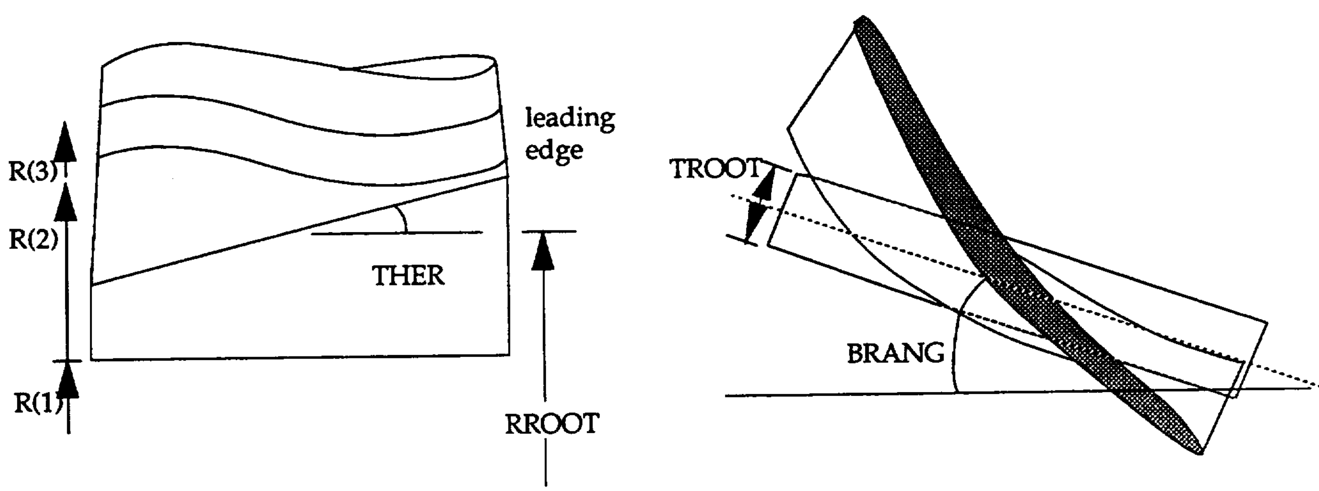


Figure 2.6. Blade Root Angle and Neck Description

CARD A10

Contents: Number of Blades

1	2	3	4	5	6	7
						BLADES
8	16	24	32	40	48	56
						8.0

Field	Item	Format	Description
7	BLADES	F	Number of Blades.

2.3.2 DATA BLOCK B: Approximate Model Input

This block contains additional approximate model input, scaling factors for geometry, etc.

CARD B1a

Contents: Problem Definition

1	2	3	4	5	6	7	8	9	10	11
NTIS	NRF	NRFOD	NCD	NLAYER	NRTFOD	NRESFF	NTIPMD	ICEPACT	BRSV	INDFL
5	10	15	20	25	30	35	40	45	55	60

5	0	5	0	1	1	0	0		1.02307	1

Field	Item	Format	Description
1	NTIS	I	Number of thickness input stations, maximum of 11, minimum of 2. Suggested value is 5.
2	NRF	I	Number of roots calculated by flutter analysis, maximum of 5.
3	NRFOD	I	Number of roots for both local and root foreign object damage (FOD) analysis. Suggested value is 5. If = 0, FOD/Ice Impact analysis is not made.
4	NCD	I	Defines the blade type: = 0: solid (isotropic/orthotropic) = 1: hollow = 2: superhybrid = 3: composite
5	NMATRL	I	Number of layers for blade. If NCD=0: enter 1 If NCD=1: enter 2 If NCD=2: enter 4 If NCD=3, NMATRL is the number of constituents in the composite (maximum of 7).
6	NRTFOD	I	Root foreign object damage option: = 0: not calculated = 1: calculated

7	NRESFF	I	Resonance margin criteria: = 0: resonance margins calculated = 1: forcing function calculated = 2: both of the above

Notes:

1. Excitation orders for which margins are calculated are input on Card B5.
2. If NRESFF=1, minimum resonance margin will be based on maximum permissible vibratory and steady stress combination on the blade which satisfies the Modified Goodman Diagram (Figure 2.7).
3. When NRESFF=2, the limiting case (either the specified resonance margin or maximum permissible blade stress) will govern.

8	NTIPMD	I	Tipmode search (required if a tip plate vibratory mode constraint is desired): = 0: no search = 1: number of modes tested for tip (5 maximum) Note: if NTIPMD > 0 and no tipmodes are found, tipmode defaults to fifth mode.
9	ICEPACT	I	= 0: ice impact analysis is not performed. = 1: ice impact analysis performed.
10	BRSV	F	Root chord length for which optimization will begin, inches. All coordinate input will be scaled by BRSV/coordinate input root chord.
11	INDFL	I	Index for failure criterion selection: = 1: Modified Distortion Energy (MDE) criterion = 2: Hoffman failure criterion

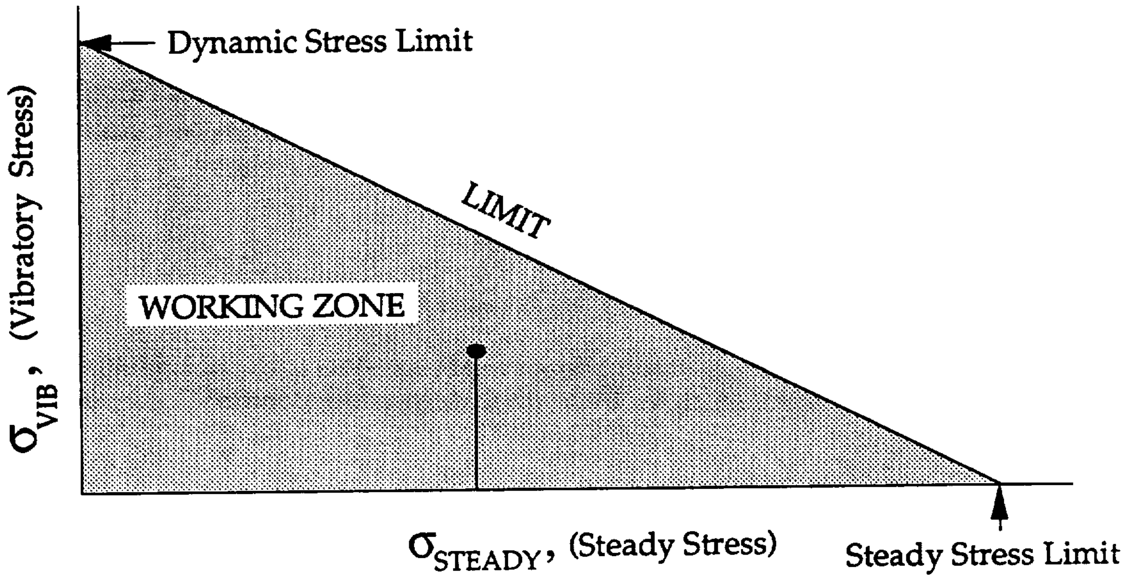


Figure 2.7. Location of the Worst Vibratory and Steady Stress Combination on the Modified Goodman Diagram

CARD B1b

Contents: Frequency Correction Factors

1	2	3	4	5	6
CF1	CF2	CF3	CF4	CF5	CFT
5	10	15	20	25	30
1.000	1.000	1.000	1.000	1.000	1.000

Field	Item	Format	Description
1	CF1	F	First mode correction factor. Default = 1.0. $CF = \frac{\text{Refined Analysis Frequency}}{\text{Approximate Analysis Frequency}}$
2	CF2	F	Second mode correction factor. Default = 1.0.
3	CF3	F	Third mode correction factor. Default = 1.0.
4	CF4	F	Fourth mode correction factor. Default = 1.0.
5	CF5	F	Fifth mode correction factor. Default = 1.0.
6	CFT	F	Tipmode correction factor. Default = 1.0.

CARD B2

Contents: Airfoil Coordinate Input in Data Block A Will be Scaled to Reflect These Starting Values of Maximum Thickness.

1	2	3	4						
IST(1)	VALT(1)	IST(2)	VALT(2)	....	NTIS times				
2	10	12	20						
2	0.8927	5	0.1447	7	0.0837	9	0.0576	11	0.0336

Field	Item	Format	Description
1	IST(1)	I	Station number (as referenced to Block B).
2	VALT(1)	F	Thickness, inches.

Alternate NTIS Times

Note: IST(NTIS) must correspond to the blade tip.

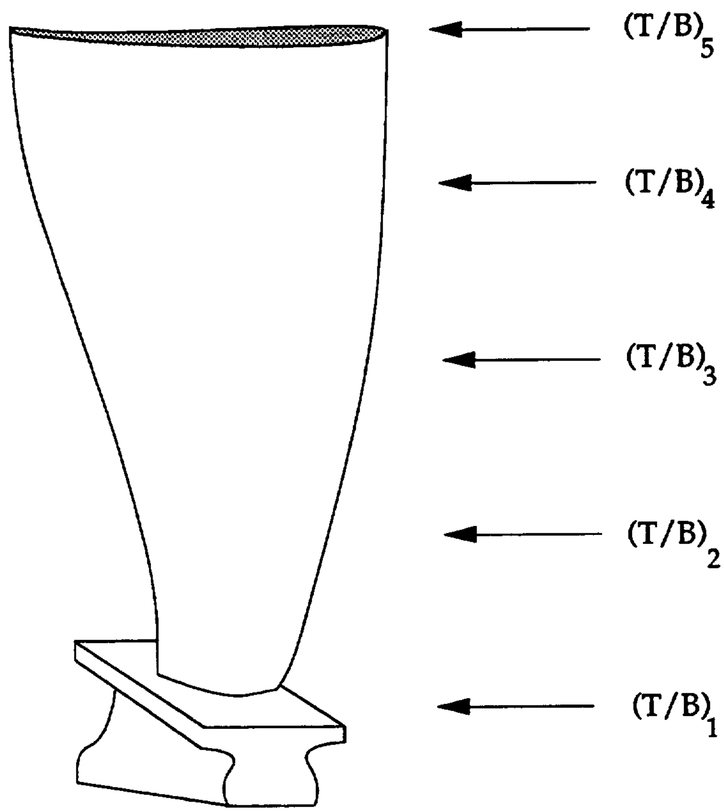


Figure 2.8. Typical Station Locations for Airfoil Maximum Thickness Starting Values

CARD B3 (Required If NRF > O on Card B1a)

Contents: Supersonic flutter analysis input control.

1	2	3	4
	TEMPST		NAC
10	20	35	40
	100.0		1

Field	Item	Format	Description
2	TEMPST	F	Inlet static temperature, °F.
4	NAC	I	Number of aerodynamic stations. Note: At present, only one station is allowed.

CARD B4 (Required If NRF > 0 on Card Bla)

Contents: Aerodynamic Data for Flutter Calculation. Input NAC Times.

1	2	3	4
VOM(I)	ARAD(I)		STPRS(I)
10	20	30	40
2.0	12.25		14.0

Field	Item	Format	Description
1	VOM(I)	F	Relative Inlet Mach Number (strictly > 1.0).
2	ARAD(I)	F	Corresponding radius in inches.
3	STPRS(I)	F	Inlet static pressure, lbf/ft^2.

CARD B5

Contents: Speed and Excitation Orders for Resonance Margin Calculation

1	2	3	4	5		
SPDRL	SPDMC	NORD	IORD(1)	IORD(2)	....	NORD times
10	20	25	30	35		
4100.0	3900.9	3	1	2	3	

Field	Item	Format	Description
1	SPDRL	F	Redline speed, RPM.
2	SPDMC	F	Minimum cruise speed, RPM.
3	NORD	I	Number of excitation orders input, maximum of 5.
4	IORD(I) I = 1, NORD	I	Order number.

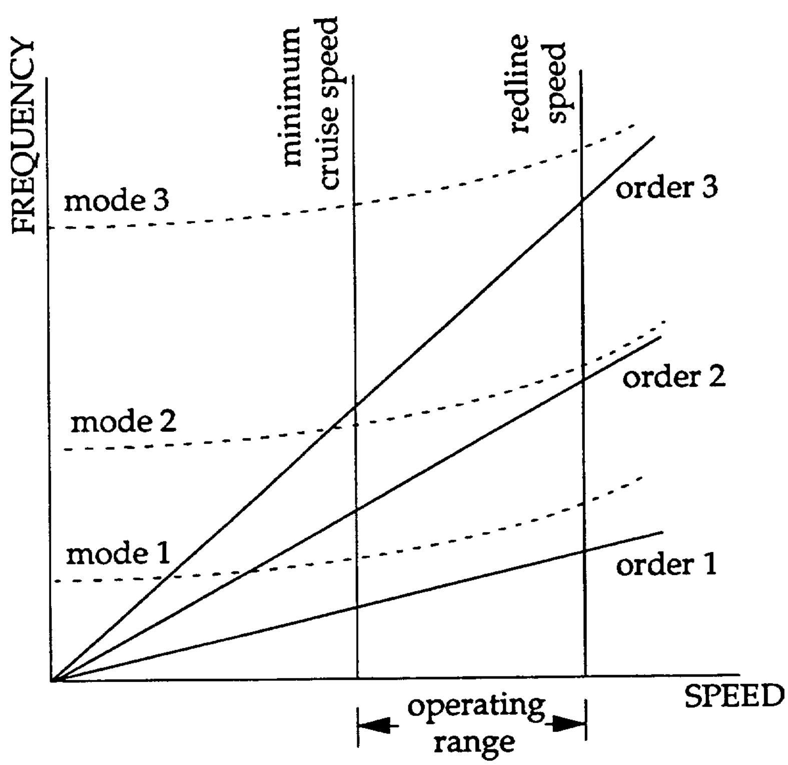


Figure 2.9. Resonance Diagram for a Successfully Tuned Blade (No Response Crossings Within 5 Percent of the Speed Operating Range)

CARD B6a (Required If NRFOD > 0 and ICEPACT=0 on Card B1a)

Contents: Local Foreign Object Damage Input

1	2	3	4	5	6
R	VP	THETA	RHO	TSTEP	BETA
10	20	30	40	50	60
0.5	2000.0	30.0	0.000076	0.00001	0.0

Field	Item	Format	Description
1	R	F	Bird radius, inches.
2	VP	F	Bird velocity, inches/sec.
3	THETA	F	Impact angle relative to ALPHA on Card B5, radians (see Figure 2.10). THETA can be calculated as follows: THETA = ALPHA (at impact radius) - Φ where $\Phi = TAN^{-1}((60*V_P)/(2\pi * \text{blade impact radius} * RPM))$.
4	RHO	F	Bird density, $lb.sec^2/in^4$.
5	TSTEP	F	Timestep, in seconds. $1x10^{-5}$ recommended.
6	BETA	F	Modal damping, 0.0 is recommended.

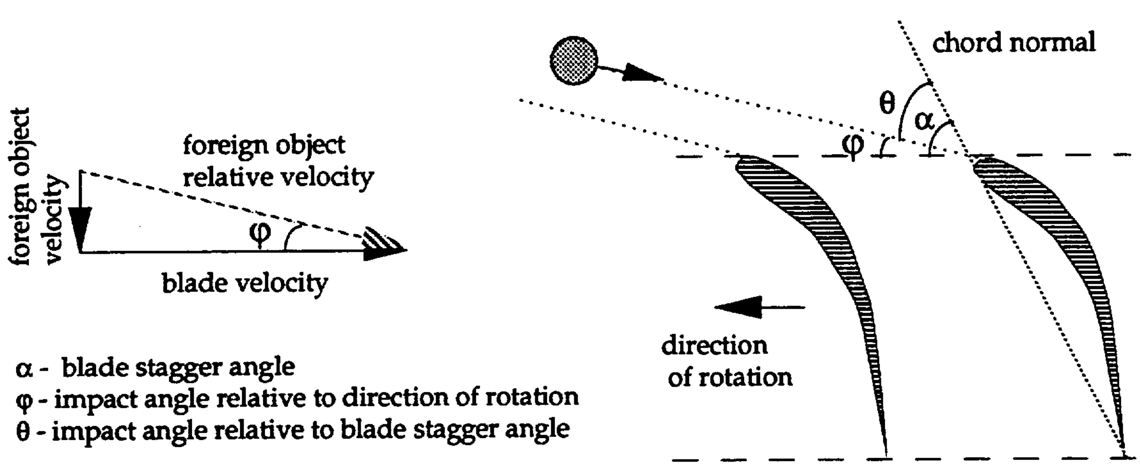


Figure 2.10. Geometry of Foreign Object Impact on the Blade

CARD B6b (Required If NRFOD > 0 and ICEPACT=1 on Card Bla)

Contents: Ice Impact Analysis

1	2	3	4	5	6	7
ALNGTH	AWIDTH	ATHICK	VP	RHO	TSTEP	BETA
10	20	30	40	50	60	70
0.700	0.700	0.700	100.00	0.000084	0.00001	0.0

Field	Item	Format	Description
1	ALNGTH	F	Length of ice block, inches.
2	AWIDTH	F	Width of ice block, inches.
3	ATHICK	F	Thickness of ice block, inches.
4	VP	F	Ice velocity, knots.
5	RHO	F	Ice density, $lb.sec^2/in^4$.
6	TSTEP	F	Time step, in seconds, $1x10^{-05}$ recommended
7	BETA	F	Modal damping, 0.0 is recommended.

Notes:

Although the input required for defining the ice size is in terms of length, width, and thickness, BLASIM computes an equivalent radius of the spherical ice, and calls the Foreign Object Damage (FOD) routines. A schematic of a spherical ice impacting on a blade is shown in Figure 2.10. The impact force is a function of the foreign object velocity as well as the blade velocity.

CARD B7 (Required If NRFOD > 0 on Card Bla)

Contents: Foreign Object Damage Input (continued)

1	2	3	4	5
FACT1	FACT2	NREF	NSTEP	NIMPACT
10	20	25	30	40
0.500	0.900	16	40	1

Field	Item	Format	Description
1	FACT1	F	Starting point along the span for impact modeling expressed as a fraction. (Figure 2.11)
2	FACT2	F	Ending point along the span for impact modeling expressed as a fraction. (Figure 2.11)
3	NREF	I	Leading edge impact node for local foreign object damage. Normally use 16. (Figure 2.11)
4	NSTEP	I	Number of timesteps required. 40 is suggested.
5	NIMPACT	I	Number of consecutive ice impacts desired with geometry update. The code provides output for pre-and-post ice impact conditions for the requested analyses.

Notes:

Figure 2.11 shows the local mesh used for ice impact analysis. The region between closest global stations to FACT1 and FACT2 will be subdivided into 7 equal stations with 35 nodes. The schematic of a typical re-meshed region is in Figure 2.11. If the impact node is 16, impact will take place approximately half way between FACT1 and FACT2. For example, if FACT1=0.5 and FACT2=0.9, the impact will be at the closest node to 0.7 (70%). It is important to note that the impact node is in the local system.

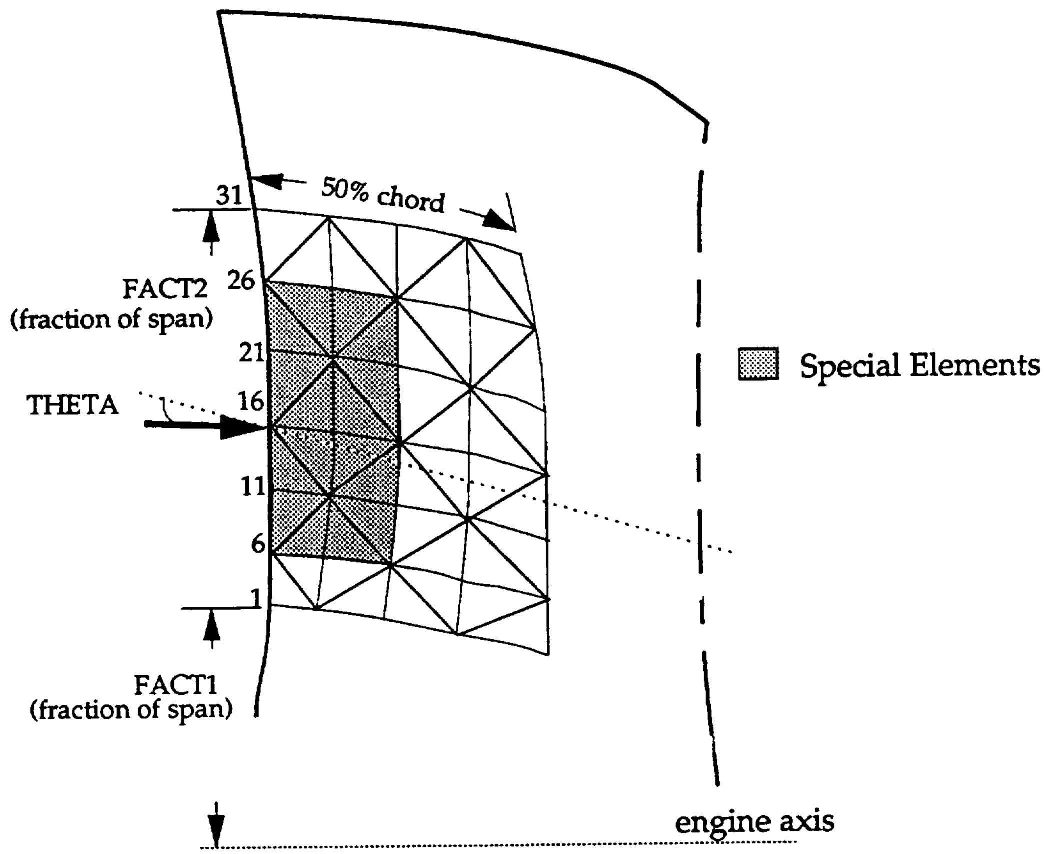


Figure 2.11. Local Foreign Object Damage Model

CARD B8a **(Required Only If Composite Ply Properties are Input)**

Contents: Material Properties (Input NMATRL Values)

1	2	3	4	5
E11(I)	E22(I)	V12(I)	G12(I)	RH(I)
10	20	30	40	50
0.165E8	0.165E8	0.300	0.634E7	0.00044

Field	Item	Format	Description
1	E11(I)	E	Youngs modulus in primary (1-1) direction, psi.
2	E22(I)	E	Youngs modulus in secondary (2-2) direction, psi.
3	V12(I)	F	Poissons ratio.
4	G12(I)	E	Shear modulus, psi.
5	RH(I)	F	Mass density, lb sec^2/in^4.

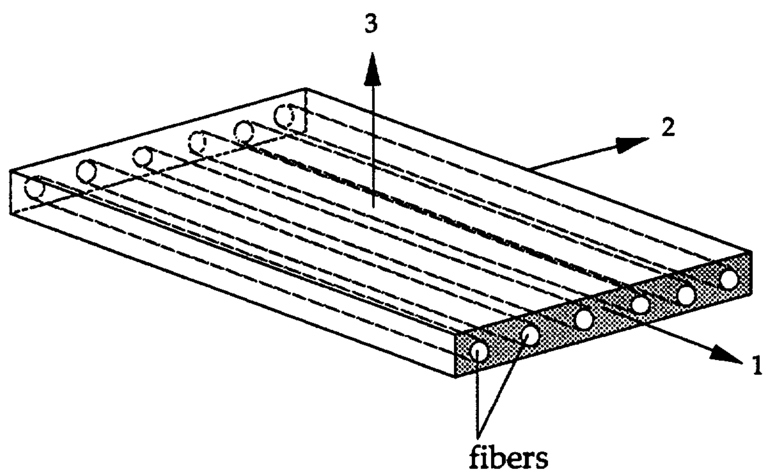


Figure 2.12. Unidirectionally Reinforced Lamina

CARD B8b **(Required If NCD=3 and Fiber-Matrix Combinations are Input)**

Contents: Specification of fiber/matrix combinations (Input NMATRL Values)

1	2	3	4	5	6	7	8
A1	FBR(I)	MTR(I)	FVR(I)	VD(I)	TU(I)	TC(I)	PMOIST(I)
7	14	18	26	34	42	50	58

MATCARD	T300	EPOC	0.4	0.0	70	70	1.0

Field	Item	Format	Description
1	A1	A7	Must Enter MATCARD.
2	FBR(I)	A4	Keyword for fiber, see list below.
3	MTR(I)	A4	Keyword for matrix, see list below.
4	FVR(I)	F	Fiber volume ratio.
5	VD(I)	F	Void volume ratio.
6	TU(I)	F	Use temperature.
7	TC(I)	F	Cure temperature.
8	PMOIST(I)	F	Percent moisture per weight.

Notes:

The ICAN code [3] uses a dedicated Data Bank containing properties for a large number of fibers and matrices. A complete listing of the Data Bank can be found in Section B.4 of Appendix B. Some of the popular fibers and matrices are listed below for user's convenience.

Fiber Keyword	*Description*	*Matrix Keyword*	*Description*
T300	Graphite	EPOC	Epoxy
P100	Graphite (High Modulus)	IMLS	Inter. Modulus Low Strength
HMSF	Surface Fiber (High Modulus)	IMHS	Inter. Modulus High Strength
SGLA	S-Glass	HMHS	High Modulus High Strength
EGLA	E-Glass	POLY	Polyimide
SW4M	Stainless Steel Wire	SSLA	Stainless Steel
TITF	Titanium	TIT6	Titanium
TUNG	Tungsten	FECR	Superalloy
SICA	Silicon Carbide on Alum.	ALTX	Aluminum
BOR5	Boron (5 Mil. Diameter)	BORM	Boron

CARD B9 (Required If NCD = 1 on Card Bla)

Contents: Data Associated With a Hollow Blade Design

1	2	3	4	5	6	7
DLE	DTE	DROOT	DDTIP	TTI	TLT	BTA
10	20	30	40	50	60	70
0.2500	0.500	3.00	7.00	0.0005	0.0005	0.00

Field	Item	Format	Description
1	DLE	F	Distance to hole from leading edge, inches.
2	DTE	F	Distance to hole from trailing edge, inches.
3	DROOT	F	Distance to hole from airfoil root, inches.
4	DTIP	F	Distance to hole from airfoil, tip, inches.
5	TTI	F	Thickness of skin, inches.
6	TLT	F	Thickness of inlay, inches.
7	BTA	F	Inlay fiber angle, degrees.

Notes:

Figure 2.13 shows the dimensions and layup associated with a hollow blade design. Two sets of material properties are required for the hollow blade: the first material defines the skin properties and the second defines the inlay properties. BLASIM treats the hollow section as a third material by defining a material of a very low modulus and high strength. If PREBLASIM is used to generate BLASIM input file, the material properties of a hollow blade are automatically written in the input file.

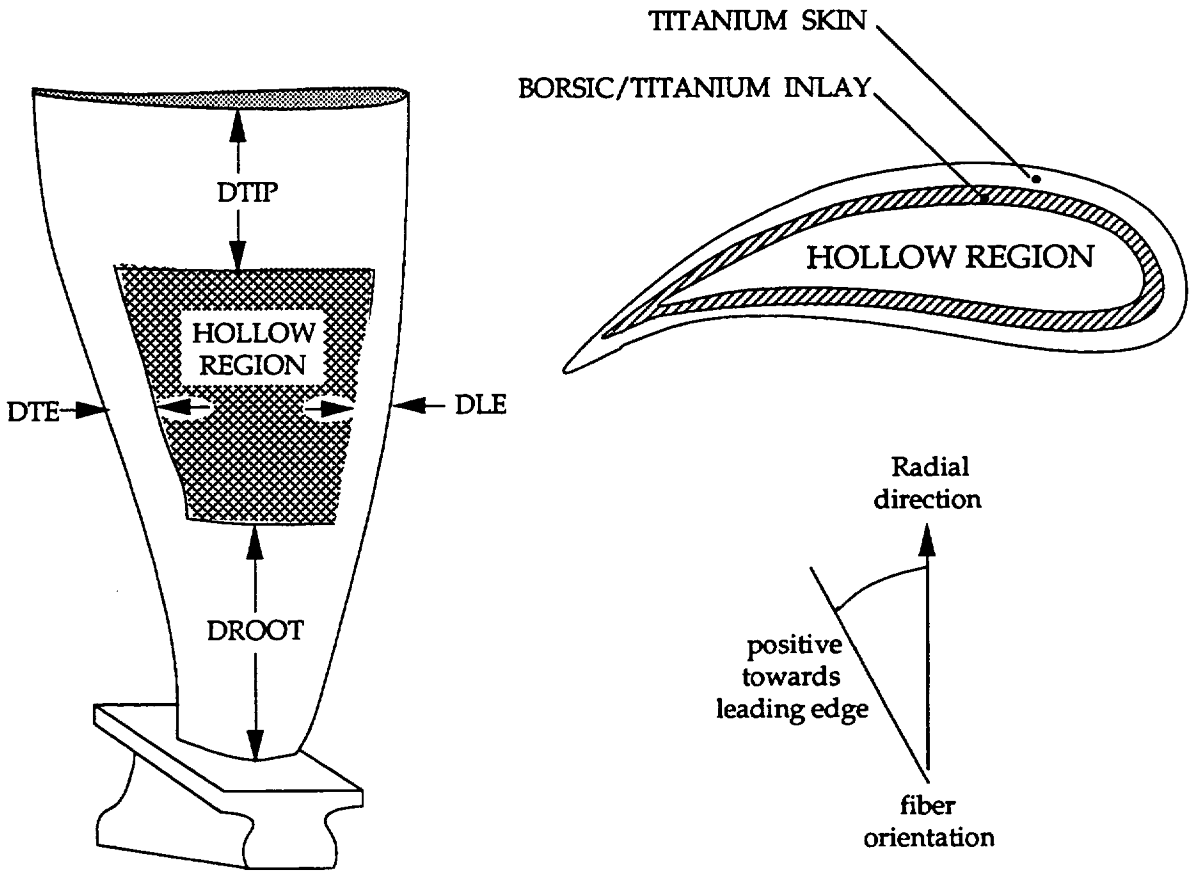


Figure 2.13. Dimensions and Layup Associated With a Hollow Blade Design

CARD B9a (Required If NCD = 2 on Card Bla)

Contents: Data Associated with a Superhybrid Blade Design.

1	2	3	4	5	6
TIS	TIC	PCBA	BAA	GEA	AMPA
10	20	30	40	50	60
0.005	0.005	50.0	0.0	0.0	0.0

Field	Item	Format	Description
1	TIS	F	Skin thickness, inches.
2	TIC	F	Center thickness, inches.
3	PCBA	F	Outer composite percent (remaining is inner composite).
4	BAA	F	Outer composite fiber angle, degrees.
5	GEA	F	Inner composite fiber angle, degrees.
6	AMPA	F	Added mass patch option. If AMPA = 0: No added mass. If AMPA > 0: Added mass option active, and AMPA reflects mass per inch^2, lb.sec^2/in^4.

Notes:

Figures 2.14 shows the layup associated with a superhybrid blade design where four materials are required. If PREBLASIM is used to generate BLASIM input file, the material properties of a superhybrid blade are automatically written in the input file.

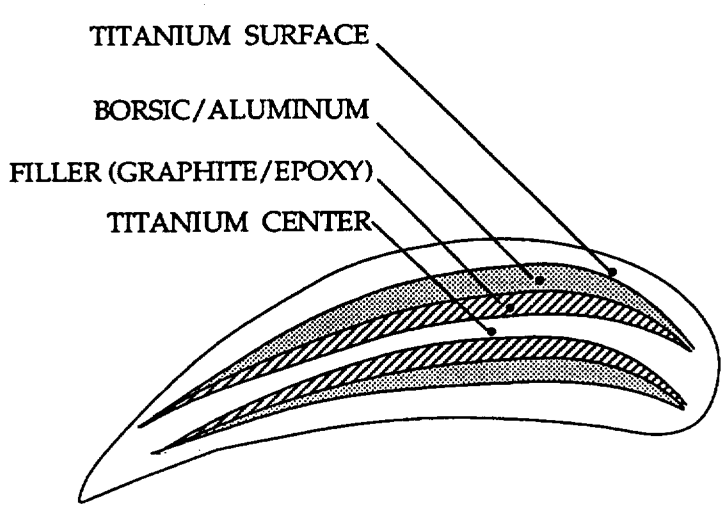


Figure 2.14. Layup Associated with a Superhybrid Blade Design

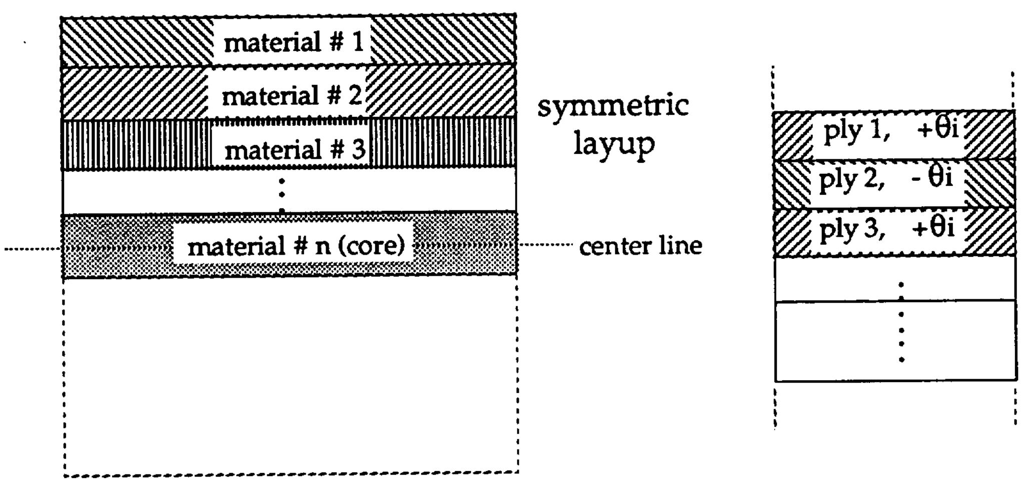
CARD B9b (Required If NCD = 3 on Card Bla)

Contents: Layer Thickness for Composite Blade Design.

1	2	3	4	5	6	7
THKDST(1)	THKDST(2)	THKDST(3)	THKDST(4)	THKDST(5)	THKDST(6)	THKDST(7)
8	16	24	32	40	48	56

0.005	0.005	0.005	0.005			

Field	Item	Format	Description
1-7	THKDST	F	Initial layer thickness, inches (Figure 2.15).



(a) Material Layup

(b) Fiber Orientation in i^{th} Material

Figure 2.15. Layer Configuration of a Composite Blade

CARD B9c (Required If NCD = 3 on Card Bla)

Contents: Ply Angles for Composite Blade Design.

1	2	3	4	5	6	7
PLYDST(1)	PLYDST(2)	PLYDST(3)	PLYDST(4)	PLYDST(5)	PLYDST(6)	PLYDST(7)
8	16	24	32	40	48	56
0.000	45.0	-45.0	0.000			

Field	Item	Format	Description
1-7	PLYDST	F	First ply angles for I^{th} composite material, degrees (Figure 2.15).

CARD B9d (Required If NCD = 3 on Card Bla)

Contents: Ply thickness for composite blade design.

1	2	3	4	5	6	7
THKLYR(1)	THKLYR(2)	THKLYR(3)	THKLYR(4)	THKLYR(5)	THKLYR(6)	THKLYR(7)
8	16	24	32	40	48	56
0.005	0.005	0.005	0.005			

Field	Item	Format	Description
1-7	THKLYR	F	Ply thickness of I^{th} composite material, inches (Figure 2.15).

Notes:

(a) Material Layer Configuration

The program computes the number of plies of each material needed to make the layer thickness of material i equal THKDST (i) (Figure 2.15a).

1. In any given element, if the element total thickness can accommodate 1, 2, 3,...,n-1 materials to their specified maximum limit, the remaining thickness is assigned to the n^{th} material (core).
2. If the total thickness can not accommodate all the material layers to their limit, plies are deleted from the material layers in the order (n-1), (n-2), ... 2. In otherwords, material 1 is always present and plies in $(n-1)^{th}$ material are deleted first.
3. If the element thickness is less than the twice the thickness of material 1 (skin), element thickness is adjusted to be equal to that value.

(b) Fiber Orientation

The layup is assumed symmetrical with angles *alternating* in sign starting from the specified value *within a material layer* (Figure 2.15b).

CARD B9e

Contents: Blade cross-section offsets.

1	2	3	4	5	6
ACLX	BCLX	CCLX	ACLY	BCLY	CCLY
8	16	24	32	40	48
0.000	0.000	0.000	0.000	0.000	0.000

Field	Item	Format	Description
1	ACLX	F	See below
2	BCLX	F	"
3	CCLX	F	"
4	ACLY	F	"
5	BCLY	F	"
6	CCLY	F	"

Notes:

Offsets of spanwise cross-sections from a straight line perpendicular to a straight line perpendicular to the engine axis are defined by:

$$x = ACLX * Z + BCLX * Z^2 + CCLX * Z^3$$

$$y = ACLY * Z + BCLY * Z^2 + CCLy * Z^3$$

where Z is a spanwise variable, y is chordwise, and x is transverse.

CARD B10 (Required If AMPA $\neq 0$ on Card B9a)

Contents: Local Increased Density Input

1	2	3	4
ADLE	ADTE	ADROOT	ADTIP
10	20	30	40
0.250	0.500	3.00	7.00

Field	Item	Format	Description
1	ADLE	F	Distance to patch from leading edge, inches.
2	ADTE	F	Distance to patch from trailing edge, inches.
3	ADROOT	F	Distance to patch from blade root, inches.
4	ADTIP	F	Distance to patch from blade tip, inches.

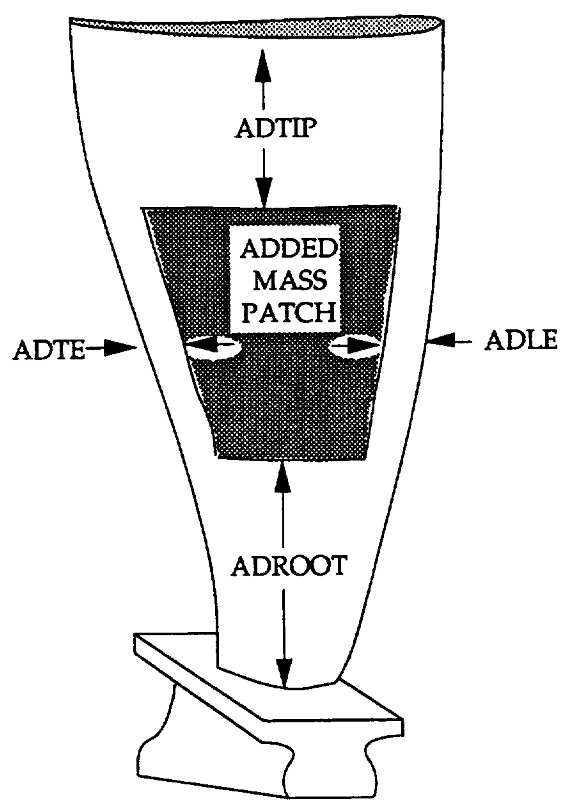


Figure 2.16. Dimensions Associated With a Local Increased Density Blade

CARD B11

Contents: Material Strength Limits. Input NMATRL Values.

1	2	3	4	5	6
X1T(I)	X1C(I)	X2T(I)	X2C(I)	S6P(I)	S6M(I)
10	20	30	40	50	60
7.4E05	7.4E05	7.4E05	7.4E05	4.4E04	4.4E04

Field	Item	Format	Description
1	X1T	E	Ultimate tensile strength in fiber direction, psi.
2	X1C	E	Ultimate compressive strength in fiber direction, psi.
3	X2T	E	Ultimate tensile strength perpendicular to fiber direction, psi.
4	X2C	E	Ultimate compressive strength perpendicular to fiber direction, psi.
5	S6P	E	Ultimate shear strength in x-y direction, psi.
6	S6M	E	Ultimate shear strength in y-x direction, psi.

Notes:

1. Input all strengths with positive value.
2. S6P and S6M are usually equal.

2.3.3 DATA BLOCK C: Boundary Condition Data

The boundary conditions and Guyan reduction data are defaulted in BLASIM. The degrees of freedom at the root of the blade are restrained. This block is included in BLASIM.INP if the user decides to modify the boundary conditions and Guyan reduction data.

CARD C1

Contents: Title

1
A

23

BOUNDARY CONDITION DATA

Field	Item	Format	Description
1	A	A23	must enter BOUNDARY CONDITION DATA

CARD C2

Contents: Boundary condition data

1	2	3	4	5	6	7	8	9
A1	I1	A3	A4	I2	A5	I3	A6	I4
8	16	24	32	40	48	56	64	72
BCS SET	1	SUPPRESS	DOFS	123456	NODES	1	THRU	5

Field	Item	Format	Description
1	A1	A8	Boundary data mnemonic, see below.
2	I1	I8	Optional identification.
3-4	A3-A4	A16	Mnemonic, see below.
5	I2	I8	Suppressed degrees of freedom.
6	A5	A8	Mnemonic
7	I3	I8	Starting node to which boundary condition apply.
8	A6	A8	Mnemonic.
9	I4	I8	Final node to which boundary conditions apply.

Of the first mnemonic (BCS SET), only the initial B is required.

CARD C3

Contents: Analysis set data indicator.

1
A

32

```
ASET DATA (GUYAN REDUCTION)
```

Field	Item	Format	Description
1	A	A32	Item indicates beginning of analysis set (ASET) data. The first character must be A. Suggestion: ASET DATA (Guyan Reduction).

CARD C4

Contents: Analysis Set Data

1	2	3	4	5	6	7	8	9	10
A1	A2	I1	A3	I2	I3	I4	I5	I6	I7
8	16	24	32	40	48	56	64	72	80
ANALYZE	DOFS	2	NODES	21	23	25	31	33	35

Field	Item	Format	Description
1-2	A1-A2	A16	Mnemonic
3	I1	I8	Analyzed degree of freedom at nodes.
4	A3	A8	Mnemonic
5-10	I2-I7	6I8	Nodes at which degrees of freedom in field 3 are analyzed

Input two C4 cards. Each analysis set must contain six nodes. The total number of analysis degrees of freedom must equal 24. All mnemonics are optional.

2.3.4 DATA BLOCK D: Pressure Data

This block is to be included in *BLASIM.INP* if the pressure load is applied.

CARD D1

1
A

23

ELEMENT PRESSURE DATA

Field	Item	Format	Description
1	A	A21	must enter ELEMENT PRESSURE DATA

CARD D2

1	2	3
A1	A2	PR
8	16	24
PRESSURE	1	5.0

Field	Item	Format	Description
1	A1-A2	A16	Any 16 character mnemonic
2	PR	F8	Net pressure on element

Enter one D2 card per element (total of 80). Fields A1-A2 may be used to identify card type and element number

2.3.5 DATA BLOCK E: Fatigue Life Data (Goodman Diagram)

This block is to be included in *BLASIM.INP* if fatigue life analysis is desired.

CARD E1

1
A

17

```
FATIGUE LIFE DATA
```

Field	Item	Format	Description
1	A	A32	must enter FATIGUE LIFE DATA

CARD E2

A	STL
16	24
STATIC	130000.

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	STL	F8	Static limit

CARD E3

1	2
A	DNL
16	24
DYNAMIC	130000.

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	DNL	F8	Dynamic Limit

CARD E4

1	2
A	MULT
16	24
MULTIPLE	0.000

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	MULT	F8	Multiple of static pressure used to compute forcing function

CARD E5

1	2
A	TMLT
16	24

TMELT	2000.0

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	TMLT	F8	Melting Temperature

CARD E6

1	2
A	TREF
8	16

TREF	100.0

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	TREF	F8	Reference Temperature

CARD E7

1	2
A	TR
8	16
TROOT	100.0

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	TR	F8	Root (current) Temperature

CARD E8

1	2
A	EXP
8	16

EXP	1.0

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	EXP	F8	Exponent

CARD E9

1	2
A	FRCFN
8	16
FRCFN	2.0

Field	Item	Format	Description
1	A	A8	Any 8 character mnemonic
2	FRCFN	F8	Forcing function factor

SECTION 3.0

VALIDATION TEST CASES

Four validation test cases for the static and modal analyses capabilities of BLASIM are included in this section. The results from static analysis are compared to MSC/NASTRAN [5] while the results from modal analysis are compared to MSC/NASTRAN, MARC [6], and MHOST [7].

3.1 SR3 Propfan Blade Under Centrifugal Loading

In this test case, a propfan blade made of aluminum material is subjected to centrifugal loading of 2000 rpm. Figure 3.1 shows the geometry and finite element grid of the SR3 propfan blade used. The blade has a uniform thickness of 0.2 inches.

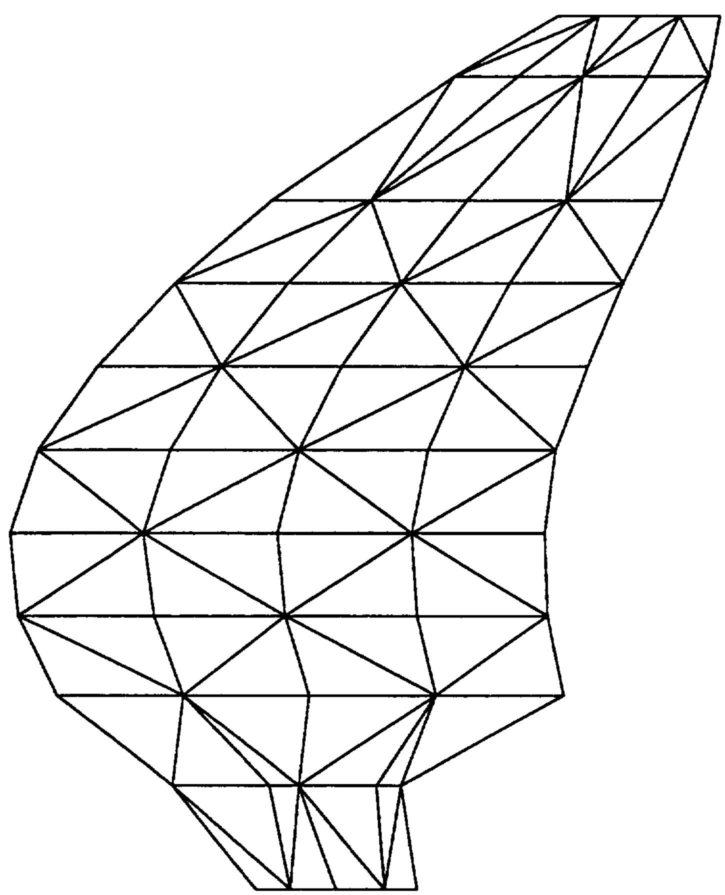


Figure 3.1. Geometry and Finite Element Mesh of the SR3 Propfan Blade

The input file required to analyze this blade using the BLASIM program is listed below:

```
sr3 swept propfan aluminum blade , rotational load only
NASTRAN GEOMETRY TYPE                                                     CARD A2
 2000.0                          5.0      1.0                             CARD A3
1                                                          2.0            CARD A4
GRID         1          1.7000  0.0427 -0.6987  0.2000                    CARD A6a
GRID         2          1.7000  0.0244 -0.3992  0.2000                    CARD A6a
GRID         3          1.7000  0.0000  0.0000  0.2000                    CARD A6a
GRID         4          1.7000 -0.0244  0.3992  0.2000                    CARD A6a
GRID         5          1.7000 -0.0427  0.6987  0.2000                    CARD A6a
GRID         6          2.9300 -0.1929 -1.4174  0.2000                    CARD A6a
GRID         7          2.9300 -0.1015 -0.5853  0.2000                    CARD A6a
GRID         8          2.9300 -0.0724 -0.3390  0.2000                    CARD A6a
GRID         9          2.9300  0.0087  0.3512  0.2000                    CARD A6a
GRID        10          2.9300  0.0291  0.5578  0.2000                    CARD A6a
GRID        11          4.0000 -0.6293 -2.4260  0.2000                    CARD A6a
GRID        12          4.0000 -0.3548 -1.3261  0.2000                    CARD A6a
GRID        13          4.0000 -0.1202 -0.2297  0.2000                    CARD A6a
GRID        14          4.0000  0.0895  0.8650  0.2000                    CARD A6a
GRID        15          4.0000  0.2999  1.9609  0.2000                    CARD A6a
GRID        16          5.0000 -0.9226 -2.7414  0.2000                    CARD A6a
GRID        17          5.0000 -0.5450 -1.5921  0.2000                    CARD A6a
GRID        18          5.0000 -0.2151 -0.4479  0.2000                    CARD A6a
GRID        19          5.0000  0.0718  0.6946  0.2000                    CARD A6a
GRID        20          5.0000  0.3207  1.8349  0.2000                    CARD A6a
GRID        21          6.0000 -1.1175 -2.8284  0.2000                    CARD A6a
GRID        22          6.0000 -0.6586 -1.6652  0.2000                    CARD A6a
GRID        23          6.0000 -0.2516 -0.5063  0.2000                    CARD A6a
GRID        24          6.0000  0.1137  0.6491  0.2000                    CARD A6a
GRID        25          6.0000  0.4278  1.8035  0.2000                    CARD A6a
GRID        26          7.0000 -1.1571 -2.5743  0.2000                    CARD A6a
GRID        27          7.0000 -0.6398 -1.4487  0.2000                    CARD A6a
GRID        28          7.0000 -0.1763 -0.3284  0.2000                    CARD A6a
GRID        29          7.0000  0.2503  0.7908  0.2000                    CARD A6a
GRID        30          7.0000  0.6269  1.9067  0.2000                    CARD A6a
GRID        31          8.0000 -1.0395 -2.0722  0.2000                    CARD A6a
GRID        32          8.0000 -0.4805 -1.0092  0.2000                    CARD A6a
GRID        33          8.0000  0.0260  0.0507  0.2000                    CARD A6a
GRID        34          8.0000  0.4973  1.1084  0.2000                    CARD A6a
GRID        35          8.0000  0.9197  2.1632  0.2000                    CARD A6a
GRID        36          9.0000 -0.7514 -1.3955  0.2000                    CARD A6a
GRID        37          9.0000 -0.1736 -0.4223  0.2000                    CARD A6a
GRID        38          9.0000  0.3542  0.5477  0.2000                    CARD A6a
GRID        39          9.0000  0.8482  1.5146  0.2000                    CARD A6a
GRID        40          9.0000  1.2962  2.4797  0.2000                    CARD A6a
GRID        41         10.0000 -0.2627 -0.5530  0.2000                    CARD A6a
GRID        42         10.0000  0.3006  0.2949  0.2000                    CARD A6a
GRID        43         10.0000  0.8169  1.1409  0.2000                    CARD A6a
GRID        44         10.0000  1.3065  1.9844  0.2000                    CARD A6a
GRID        45         10.0000  1.7529  2.8262  0.2000                    CARD A6a
GRID        46         11.5000  0.9192  1.0088  0.2000                    CARD A6a
GRID        47         11.5000  1.3469  1.5671  0.2000                    CARD A6a
GRID        48         11.5000  1.7427  2.1232  0.2000                    CARD A6a
GRID        49         11.5000  2.1224  2.6784  0.2000                    CARD A6a
GRID        50         11.5000  2.4765  3.2322  0.2000                    CARD A6a
GRID        51         12.2500  1.7253  1.9169  0.2000                    CARD A6a
GRID        52         12.2500  2.0074  2.2667  0.2000                    CARD A6a
GRID        53         12.2500  2.2727  2.6154  0.2000                    CARD A6a
GRID        54         12.2500  2.5290  2.9628  0.2000                    CARD A6a
GRID        55         12.2500  2.7682  3.3100  0.2000                    CARD A6a
```

```
          0.0    0.200    0.000      0.0                                         CARD A9
                                                       8.0                       CARD A10
  5    0    0    0    1    0    0    0    0   1.98764     1                     CARD B1a
1.0001.0001.0001.0001.0001.000                                                   CARD B1b
 2  0.2000 5  0.2000 7  0.2000 9  0.200011  0.2000                               CARD B2
  2500.000  1500.000     5    1    2    3    4    5                              CARD B5
 0.100E+08 0.100E+08   0.30000 0.385E+07   0.00025                               CARD B8
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000                                 CARD B9e
 0.400E+05 0.400E+05 0.400E+05 0.400E+05 0.220E+05 0.220E+05                     CARD B11
```

The case discussed here was also solved using MSC/NASTRAN. The results from both programs, BLASIM and MSC/NASTRAN are in very good agreement. Figure 3.2(a,b) shows a comparison plots of the displacement and stress results.

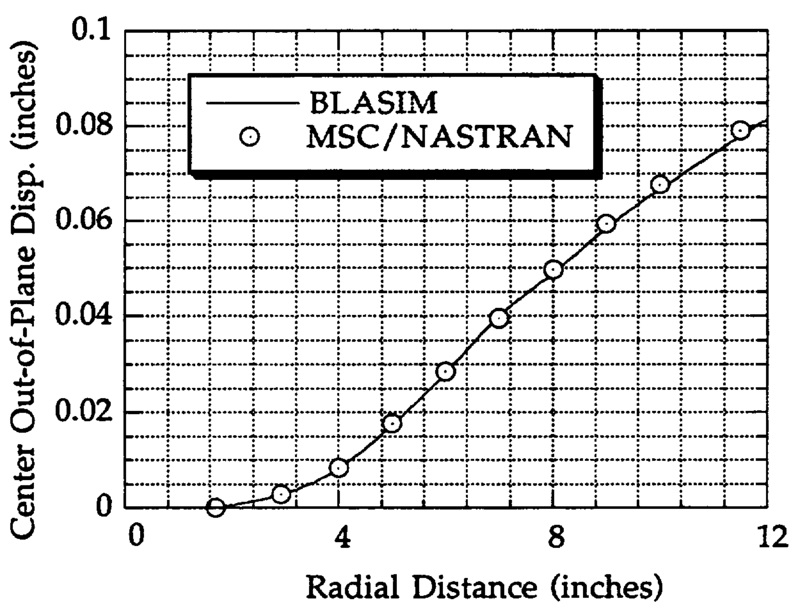


Figure 3.2a. Displacements Comparison of BLASIM and MSC/NASTRAN Results (Static Analysis - Centrifugal Loading)

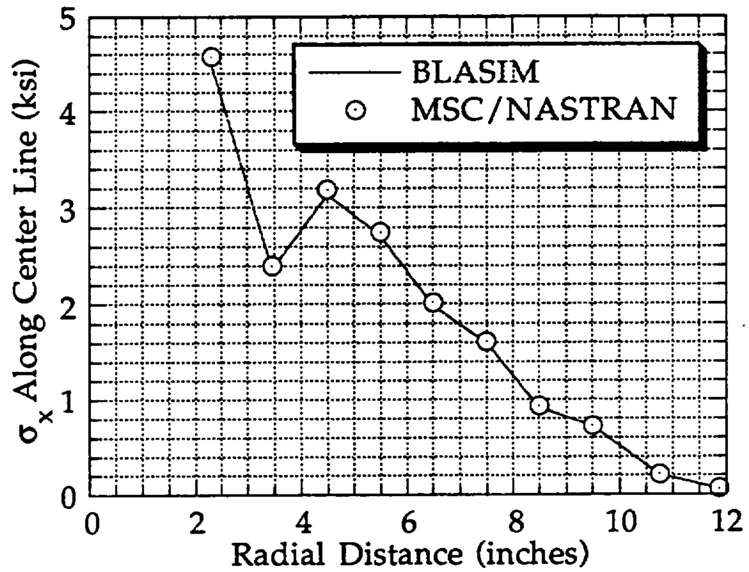


Figure 3.2b. Stress Comparison of BLASIM and MSC/NASTRAN Results
(Static Analysis - Centrifugal Loading)

3.2 SR3 Propfan Blade Under Uniform Pressure Loading

The same propfan blade is used in this case with a uniform pressure of 1 psi applied on all elements. The input file to the BLASIM code is listed below:

```
sr3 swept propfan aluminum blade , pressure load only
NASTRAN GEOMETRY TYPE                                                   CARD A2
    1.0                            5.0      1.0                         CARD A3
1                                                       2.0             CARD A4
GRID        1          1.7000  0.0427 -0.6987  0.2000                   CARD A6a
GRID        2          1.7000  0.0244 -0.3992  0.2000                   CARD A6a
GRID        3          1.7000  0.0000  0.0000  0.2000                   CARD A6a
GRID        4          1.7000 -0.0244  0.3992  0.2000                   CARD A6a
GRID        5          1.7000 -0.0427  0.6987  0.2000                   CARD A6a
GRID        6          2.9300 -0.1929 -1.4174  0.2000                   CARD A6a
GRID        7          2.9300 -0.1015 -0.5853  0.2000                   CARD A6a
GRID        8          2.9300 -0.0724 -0.3390  0.2000                   CARD A6a
GRID        9          2.9300  0.0087  0.3512  0.2000                   CARD A6a
GRID       10          2.9300  0.0291  0.5578  0.2000                   CARD A6a
GRID       11          4.0000 -0.6293 -2.4260  0.2000                   CARD A6a
GRID       12          4.0000 -0.3548 -1.3261  0.2000                   CARD A6a
GRID       13          4.0000 -0.1202 -0.2297  0.2000                   CARD A6a
GRID       14          4.0000  0.0895  0.8650  0.2000                   CARD A6a
GRID       15          4.0000  0.2999  1.9609  0.2000                   CARD A6a
GRID       16          5.0000 -0.9226 -2.7414  0.2000                   CARD A6a
GRID       17          5.0000 -0.5450 -1.5921  0.2000                   CARD A6a
GRID       18          5.0000 -0.2151 -0.4479  0.2000                   CARD A6a
GRID       19          5.0000  0.0718  0.6946  0.2000                   CARD A6a
GRID       20          5.0000  0.3207  1.8349  0.2000                   CARD A6a
GRID       21          6.0000 -1.1175 -2.8284  0.2000                   CARD A6a
GRID       22          6.0000 -0.6586 -1.6652  0.2000                   CARD A6a
GRID       23          6.0000 -0.2516 -0.5063  0.2000                   CARD A6a
GRID       24          6.0000  0.1137  0.6491  0.2000                   CARD A6a
```

```
GRID        25          6.0000  0.4278  1.8035  0.2000              CARD A6a
GRID        26          7.0000 -1.1571 -2.5743  0.2000              CARD A6a
GRID        27          7.0000 -0.6398 -1.4487  0.2000              CARD A6a
GRID        28          7.0000 -0.1763 -0.3284  0.2000              CARD A6a
GRID        29          7.0000  0.2503  0.7908  0.2000              CARD A6a
GRID        30          7.0000  0.6269  1.9067  0.2000              CARD A6a
GRID        31          8.0000 -1.0395 -2.0722  0.2000              CARD A6a
GRID        32          8.0000 -0.4805 -1.0092  0.2000              CARD A6a
GRID        33          8.0000  0.0260  0.0507  0.2000              CARD A6a
GRID        34          8.0000  0.4973  1.1084  0.2000              CARD A6a
GRID        35          8.0000  0.9197  2.1632  0.2000              CARD A6a
GRID        36          9.0000 -0.7514 -1.3955  0.2000              CARD A6a
GRID        37          9.0000 -0.1736 -0.4223  0.2000              CARD A6a
GRID        38          9.0000  0.3542  0.5477  0.2000              CARD A6a
GRID        39          9.0000  0.8482  1.5146  0.2000              CARD A6a
GRID        40          9.0000  1.2962  2.4797  0.2000              CARD A6a
GRID        41         10.0000 -0.2627 -0.5530  0.2000              CARD A6a
GRID        42         10.0000  0.3006  0.2949  0.2000              CARD A6a
GRID        43         10.0000  0.8169  1.1409  0.2000              CARD A6a
GRID        44         10.0000  1.3065  1.9844  0.2000              CARD A6a
GRID        45         10.0000  1.7529  2.8262  0.2000              CARD A6a
GRID        46         11.5000  0.9192  1.0088  0.2000              CARD A6a
GRID        47         11.5000  1.3469  1.5671  0.2000              CARD A6a
GRID        48         11.5000  1.7427  2.1232  0.2000              CARD A6a
GRID        49         11.5000  2.1224  2.6784  0.2000              CARD A6a
GRID        50         11.5000  2.4765  3.2322  0.2000              CARD A6a
GRID        51         12.2500  1.7253  1.9169  0.2000              CARD A6a
GRID        52         12.2500  2.0074  2.2667  0.2000              CARD A6a
GRID        53         12.2500  2.2727  2.6154  0.2000              CARD A6a
GRID        54         12.2500  2.5290  2.9628  0.2000              CARD A6a
GRID        55         12.2500  2.7682  3.3100  0.2000              CARD A6a
            0.0   0.200   0.000     0.0                             CARD A9
                                                  8.0               CARD A10
   5    0    0    0    1    0    0    0    0  1.98764    1          CARD B1a
1.0001.0001.0001.0001.0001.000                                      CARD B1b
 2  0.2000 5  0.2000 7  0.2000 9  0.200011  0.2000                  CARD B2
  2500.000  1500.000    5    1    2    3    4    5                  CARD B5
 0.100E+08 0.100E+08   0.30000 0.385E+07   0.00025                  CARD B8
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000                    CARD B9e
 0.400E+05 0.400E+05 0.400E+05 0.400E+05 0.220E+05 0.220E+05        CARD B11
ELEMENT PRESSURE DATA
PRESSURE       1     -1.0
PRESSURE       2     -1.0
PRESSURE       3     -1.0
PRESSURE       4     -1.0
PRESSURE       5     -1.0
PRESSURE       6     -1.0
PRESSURE       7     -1.0
PRESSURE       8     -1.0
PRESSURE       9     -1.0
PRESSURE      10     -1.0
PRESSURE      11     -1.0
PRESSURE      12     -1.0
PRESSURE      13     -1.0
PRESSURE      14     -1.0
PRESSURE      15     -1.0
PRESSURE      16     -1.0
PRESSURE      17     -1.0
PRESSURE      18     -1.0
PRESSURE      19     -1.0
```

```
PRESSURE        20      -1.0
PRESSURE        21      -1.0
PRESSURE        22      -1.0
PRESSURE        23      -1.0
PRESSURE        24      -1.0
PRESSURE        25      -1.0
PRESSURE        26      -1.0
PRESSURE        27      -1.0
PRESSURE        28      -1.0
PRESSURE        29      -1.0
PRESSURE        30      -1.0
PRESSURE        31      -1.0
PRESSURE        32      -1.0
PRESSURE        33      -1.0
PRESSURE        34      -1.0
PRESSURE        35      -1.0
PRESSURE        36      -1.0
PRESSURE        37      -1.0
PRESSURE        38      -1.0
PRESSURE        39      -1.0
PRESSURE        40      -1.0
PRESSURE        41      -1.0
PRESSURE        42      -1.0
PRESSURE        43      -1.0
PRESSURE        44      -1.0
PRESSURE        45      -1.0
PRESSURE        46      -1.0
PRESSURE        47      -1.0
PRESSURE        48      -1.0
PRESSURE        49      -1.0
PRESSURE        50      -1.0
PRESSURE        51      -1.0
PRESSURE        52      -1.0
PRESSURE        53      -1.0
PRESSURE        54      -1.0
PRESSURE        55      -1.0
PRESSURE        56      -1.0
PRESSURE        57      -1.0
PRESSURE        58      -1.0
PRESSURE        59      -1.0
PRESSURE        60      -1.0
PRESSURE        61      -1.0
PRESSURE        62      -1.0
PRESSURE        63      -1.0
PRESSURE        64      -1.0
PRESSURE        65      -1.0
PRESSURE        66      -1.0
PRESSURE        67      -1.0
PRESSURE        68      -1.0
PRESSURE        69      -1.0
PRESSURE        70      -1.0
PRESSURE        71      -1.0
PRESSURE        72      -1.0
PRESSURE        73      -1.0
```

```
PRESSURE        74      -1.0
PRESSURE        75      -1.0
PRESSURE        76      -1.0
PRESSURE        77      -1.0
PRESSURE        78      -1.0
PRESSURE        79      -1.0
PRESSURE        80      -1.0
```

Figure 3.3 (a,b) shows the comparison plots of the displacement and stress results.

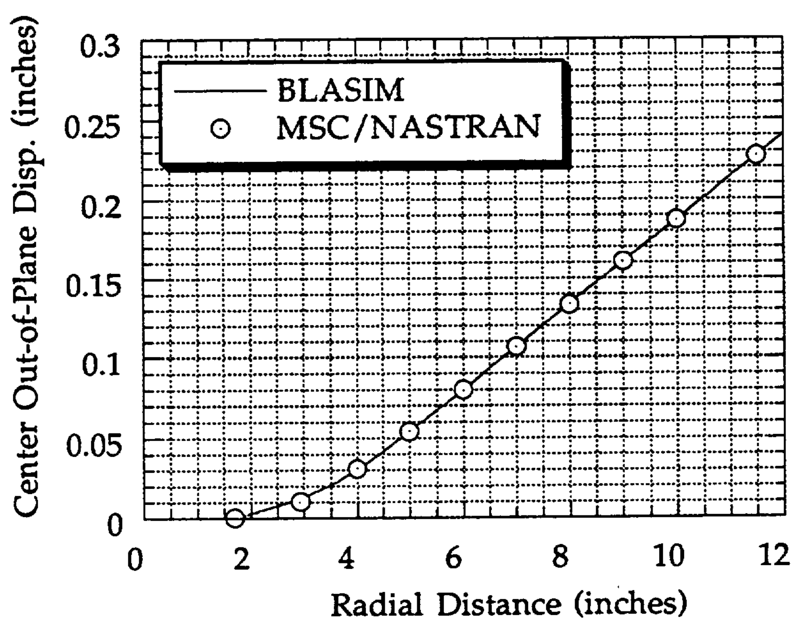


Figure 3.3a. Displacement Comparison of BLASIM and MSC/NASTRAN Results
(Static Analysis - Pressure Loading)

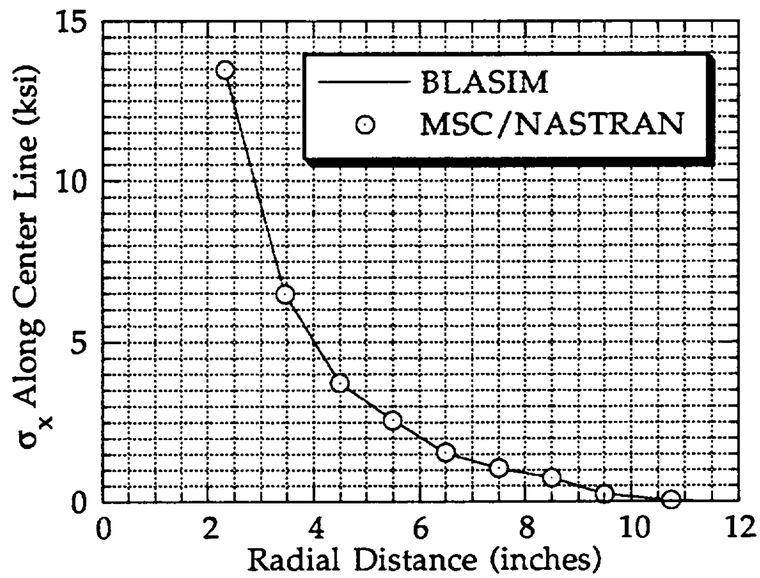


Figure 3.3b. Stress Comparison of BLASIM and MSC/NASTRAN Results
(Static Analysis - Pressure Loading)

3.3 SR2 Propfan Blade Under Centrifugal Loading

An SR2 composite propfan blade (Figure 3.4) constructed with [0,±45,0] Titanium/ Graphite-Epoxy/Titanium and subjected to a centrifugal load of 3000 rpm is analyzed using BLASIM and MSC/NASTRAN.

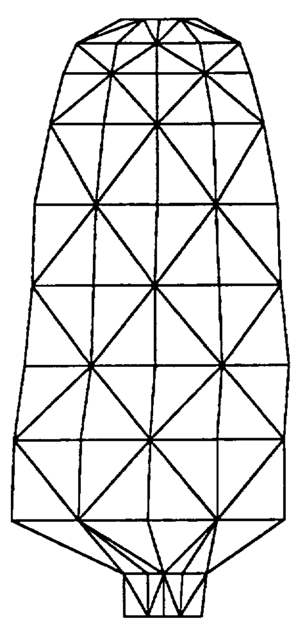


Figure 3.4. Finite Element Mesh of the SR2 Composite Propfan Blade

The input file required to analyze the composite blade using BLASIM is listed below:

```
sr2unswept composite blade
NASTRAN GEOMETRY TYPE                                                    CARD A2
  3000.0                                3.0      1.0                     CARD A3
1                                                            2.0         CARD A4
GRID            1           2.0600  0.0000 -0.4710   0.7267              CARD A6a
GRID            2           2.0600  0.0000 -0.1980   1.0125              CARD A6a
GRID            3           2.0600  0.0000  0.0000   1.0857              CARD A6a
GRID            4           2.0600  0.0000  0.1980   1.0125              CARD A6a
GRID            5           2.0600  0.0000  0.4710   0.7267              CARD A6a
GRID            6           2.7780  0.0650 -0.5500   0.6666              CARD A6a
GRID            7           2.7780  0.0510 -0.2190   0.7926              CARD A6a
GRID            8           2.7780  0.0240 -0.0200   0.8927              CARD A6a
GRID            9           2.7780 -0.0030  0.1980   0.8587              CARD A6a
GRID           10           2.7780  0.0000  0.4710   0.7465              CARD A6a
GRID           11           3.6840  0.4940 -1.5130   0.0990              CARD A6a
GRID           12           3.6840  0.2030 -0.6550   0.2737              CARD A6a
GRID           13           3.6840 -0.0540  0.1990   0.3339              CARD A6a
GRID           14           3.6840 -0.2780  1.0540   0.2339              CARD A6a
GRID           15           3.6840 -0.4710  1.9120   0.0774              CARD A6a
GRID           16           5.0360  0.6530 -1.5240   0.0688              CARD A6a
GRID           17           5.0360  0.2770 -0.6760   0.1804              CARD A6a
GRID           18           5.0360 -0.0700  0.1680   0.2059              CARD A6a
GRID           19           5.0360 -0.3900  1.0150   0.1343              CARD A6a
GRID           20           5.0360 -0.6840  1.8630   0.0356              CARD A6a
GRID           21           6.3890  0.7950 -1.5640   0.0486              CARD A6a
GRID           22           6.3890  0.3580 -0.7400   0.1198              CARD A6a
GRID           23           6.3890 -0.0450  0.0810   0.1447              CARD A6a
GRID           24           6.3890 -0.4260  0.9020   0.1122              CARD A6a
GRID           25           6.3890 -0.7760  1.7250   0.0340              CARD A6a
GRID           26           7.7420  0.8840 -1.4970   0.0362              CARD A6a
GRID           27           7.7420  0.4030 -0.7110   0.0891              CARD A6a
GRID           28           7.7420 -0.0490  0.0750   0.1064              CARD A6a
GRID           29           7.7420 -0.4800  0.8600   0.0835              CARD A6a
GRID           30           7.7420 -0.8830  1.6460   0.0260              CARD A6a
GRID           31           9.0940  0.9510 -1.4200   0.0285              CARD A6a
GRID           32           9.0940  0.4400 -0.6750   0.0702              CARD A6a
GRID           33           9.0940 -0.0500  0.0680   0.0837              CARD A6a
GRID           34           9.0940 -0.5250  0.8120   0.0651              CARD A6a
GRID           35           9.0940 -0.9780  1.5560   0.0207              CARD A6a
GRID           36          10.4470  0.9680 -1.2870   0.0233              CARD A6a
GRID           37          10.4470  0.4570 -0.6140   0.0575              CARD A6a
GRID           38          10.4470 -0.0450  0.0570   0.0684              CARD A6a
GRID           39          10.4470 -0.5400  0.7290   0.0533              CARD A6a
GRID           40          10.4470 -1.0260  1.4020   0.0173              CARD A6a
GRID           41          11.3480  0.8950 -1.1220   0.0193              CARD A6a
GRID           42          11.3480  0.4270 -0.5380   0.0484              CARD A6a
GRID           43          11.3480 -0.0370  0.0450   0.0576              CARD A6a
GRID           44          11.3480 -0.4980  0.6290   0.0449              CARD A6a
GRID           45          11.3480 -0.9550  1.2130   0.0148              CARD A6a
GRID           46          11.7990  0.8050 -0.9800   0.0137              CARD A6a
GRID           47          11.7990  0.3860 -0.4710   0.0366              CARD A6a
GRID           48          11.7990 -0.0310  0.0370   0.0435              CARD A6a
GRID           49          11.7990 -0.4460  0.5450   0.0341              CARD A6a
GRID           50          11.7990 -0.8600  1.0540   0.0107              CARD A6a
GRID           51          12.2500  0.3810 -0.4520   0.0082              CARD A6a
GRID           52          12.2500  0.1830 -0.2180   0.0283              CARD A6a
GRID           53          12.2500 -0.0140  0.0170   0.0336              CARD A6a
GRID           54          12.2500 -0.2110  0.2510   0.0265              CARD A6a
GRID           55          12.2500 -0.4080  0.4850   0.0066              CARD A6a
                0.0    1.086    0.000      0.0                           CARD A9
                                                     8.0                 CARD A10
    5    0    0    3    4    0    0    0    0  1.02307    1              CARD B1a
```

```
.0001.0001.0001.0001.0001.000                                                       CARD B1b
2  0.8927 5  0.1447 7  0.0837 9  0.057611  0.0336                                   CARD B2
 3200.000  2800.000    3    1    2    3                                             CARD B5
  16.5E06   16.5E06    0.3000   6.40E06   .000440                                   CARD B8
  32.0E06   1.0E+06    0.2500   0.70E06   .000150                                   CARD B8
  32.0E06   1.0E+06    0.2500   0.70E06   .000150                                   CARD B8
  16.5E06   16.5E06    0.3000   6.40E06   .000440                                   CARD B8
  0.005   0.005   0.005   0.005                                                     CARD B9b
  0.000   +45.0   -45.0   0.000                                                     CARD B9c
  0.005   0.005   0.005   0.005                                                     CARD B9d
  0.000   0.000   0.000   0.000   0.000   0.000                                     CARD B9e
   7.40E4    7.40E4    7.40E4    7.40E4    4.40E4    4.40E4                         CARD B11
  17.50E4   17.5E04    5.0E03    5.0E03    10.0E3    10.0E3                         CARD B11
  17.50E4   17.5E04    5.0E03    5.0E03    10.0E3    10.0E3                         CARD B11
   7.40E4    7.40E4    7.40E4    7.40E4    4.40E4    4.40E4                         CARD B11
```

The displacements obtained from BLASIM are compared to those provided by MSC/NASTRAN. The displacement results show very good agreement and are presented in Figure 3.5.

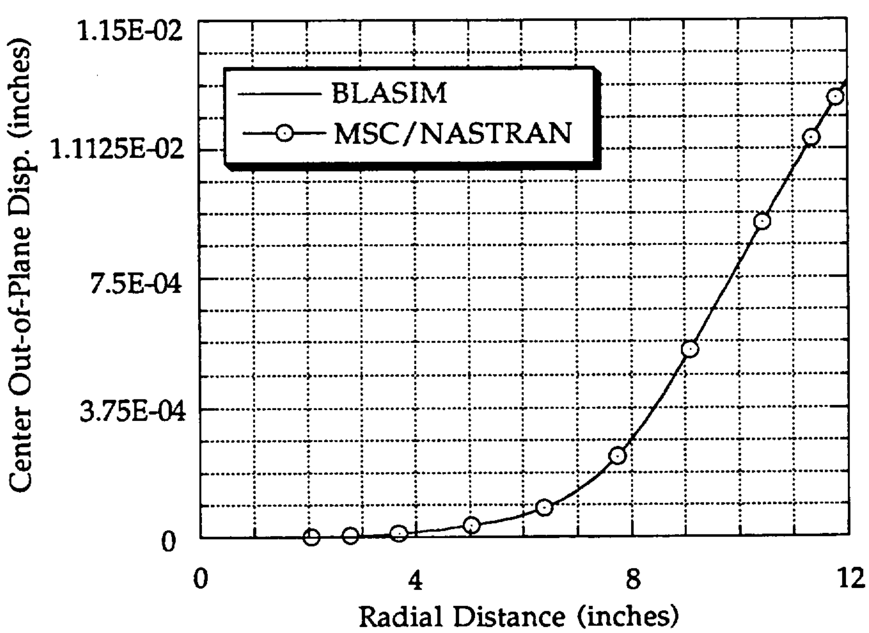


Figure 3.5. Displacements Comparison of BLASIM and MSC/NASTRAN Results (Static Analysis - Centrifugal Loading)

The stresses at the root of the blade obtained from BLASIM and MSC/NASTRAN are presented in the following table:

Source	Root Stress (psi)
BLASIM	883.93
MSC/NASTRAN	884.20

3.4 Free Vibration Analysis of an SR3 Propfan Blade

A free vibration analysis was conducted on the propfan blade used in Sections 3.1 and 3.2 to extract the first three natural frequencies. The results are compared to the solution provided by MSC/NASTRAN, MARC and MHOST. The BLASIM natural frequencies (cycles/sec) are in very good agreement with the ones from other finite element programs. A summary of the results is given:

Mode #	BLASIM	MSC/NASTRAN	MARC	MHOST
1	52.30	51.89	51.00	49.58
2	228.74	226.95	251.57	206.10
3	403.52	400.35	447.20	402.80

Notes:

The discrepancies for the second and third modes in the above table are due to the following:

1. BLASIM and MSC/NASTRAN use lumped mass method.
2. MARC and MHOST use consistent mass method.
3. BLASIM, MSC/NASTRAN, and MARC models consisted of 80 triangular elements while the MHOST model consisted of 40 quadrilateral elements.

SECTION 4.0

REFERENCES

1. MacNeal, R. H.: A Simple Quadrilateral Shell Element. Computers and Structures, vol. 8, Pergamon Press, Great Britain, 1978, pp. 175-183.

2. Brown, K.: Structural Tailoring of Engine Blades (STAEBL), Theoretical Manual,. NASA Contractor Report CR-175112.

3. Murthy, P. L. N.; and Chamis, C. C.: Integrated Composite Analyzer (ICAN), Users and Programmers Manual. NASA TP2515, 1986.

4. Abbott, I. H. and Von Doenhoff, A. E.: Theory of Wing Sections. Dover Publications, Inc., New York, 1959, page 113.

5. MSC/NASTRAN, Version 65C, User's Manual. The MacNeal-Schwendler Corporation, 1987.

6. MARC, User Information Manual, MARC Analysis Corporation, 1988.

7. The MHOST Finite Element Program, Volume II-User's Manual, NASA CR-182235, 1989.

APPENDIX A

ICE IMPACT ANALYSIS OF SR-2 BLADE

A.1 Problem Description

The SR-2 unswept titanium propfan blade under centrifugal load of 4000 rpm and uniform pressure of 5 psi is considered for analysis using BLASIM. Static, modal, ice impact, flutter, and fatigue analyses capabilities are demonstrated in this problem. The blade is subject to a single ice impact at approximately 70% of the span. The ice speed is 100 knots and its dimensions are 0.7"x0.7"x0.7". Flutter analysis is conducted at a Mach number of 1.1 with a temperature of 32 F and a pressure of one atmosphere. The fatigue analysis input parameters selected for this case include static and dynamic stress limits of 75000 and 30000 psi, respectively, with a forcing function of 1.0.

In the input file, the geometry is defined using the finite element grid. A schematic of the planform of the blade with finite element grid is shown in the Figure A.1. The listing of the complete input is given in the next section.

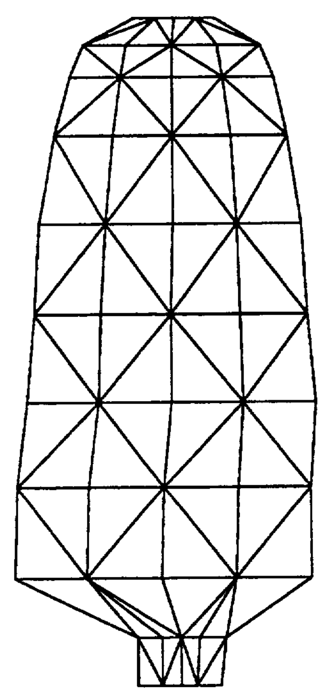


Figure A.1 Planform of the SR-2 Unswept Blade with Finite Element Grid

A.2 Input File

The interactive input generator PREBLASIM is used to create the input file to BLASIM, BLASIM.INP. Since the finite element grid option is used , a file named GRID.DAT containing the grid coordinates and thicknesses is prepared.

A listing of GRID.DAT is given below:

GRID	1	2.0600	0.0000	-0.4710	0.7267
GRID	2	2.0600	0.0000	-0.1980	1.0125
GRID	3	2.0600	0.0000	0.0000	1.0857
GRID	4	2.0600	0.0000	0.1980	1.0125
GRID	5	2.0600	0.0000	0.4710	0.7267
GRID	6	2.7780	0.0650	-0.5500	0.6666
GRID	7	2.7780	0.0510	-0.2190	0.7926
GRID	8	2.7780	0.0240	-0.0200	0.8927
GRID	9	2.7780	-0.0030	0.1980	0.8587
GRID	10	2.7780	0.0000	0.4710	0.7465
GRID	11	3.6840	0.4940	-1.5130	0.0990
GRID	12	3.6840	0.2030	-0.6550	0.2737
GRID	13	3.6840	-0.0540	0.1990	0.3339
GRID	14	3.6840	-0.2780	1.0540	0.2339
GRID	15	3.6840	-0.4710	1.9120	0.0774
GRID	16	5.0360	0.6530	-1.5240	0.0688
GRID	17	5.0360	0.2770	-0.6760	0.1804
GRID	18	5.0360	-0.0700	0.1680	0.2059
GRID	19	5.0360	-0.3900	1.0150	0.1343
GRID	20	5.0360	-0.6840	1.8630	0.0356
GRID	21	6.3890	0.7950	-1.5640	0.0486
GRID	22	6.3890	0.3580	-0.7400	0.1198
GRID	23	6.3890	-0.0450	0.0810	0.1447
GRID	24	6.3890	-0.4260	0.9020	0.1122
GRID	25	6.3890	-0.7760	1.7250	0.0340
GRID	26	7.7420	0.8840	-1.4970	0.0362
GRID	27	7.7420	0.4030	-0.7110	0.0891
GRID	28	7.7420	-0.0490	0.0750	0.1064
GRID	29	7.7420	-0.4800	0.8600	0.0835
GRID	30	7.7420	-0.8830	1.6460	0.0260
GRID	31	9.0940	0.9510	-1.4200	0.0285
GRID	32	9.0940	0.4400	-0.6750	0.0702
GRID	33	9.0940	-0.0500	0.0680	0.0837
GRID	34	9.0940	-0.5250	0.8120	0.0651
GRID	35	9.0940	-0.9780	1.5560	0.0207
GRID	36	10.4470	0.9680	-1.2870	0.0233
GRID	37	10.4470	0.4570	-0.6140	0.0575
GRID	38	10.4470	-0.0450	0.0570	0.0684
GRID	39	10.4470	-0.5400	0.7290	0.0533
GRID	40	10.4470	-1.0260	1.4020	0.0173
GRID	41	11.3480	0.8950	-1.1220	0.0193
GRID	42	11.3480	0.4270	-0.5380	0.0484
GRID	43	11.3480	-0.0370	0.0450	0.0576
GRID	44	11.3480	-0.4980	0.6290	0.0449
GRID	45	11.3480	-0.9550	1.2130	0.0148
GRID	46	11.7990	0.8050	-0.9800	0.0137
GRID	47	11.7990	0.3860	-0.4710	0.0366
GRID	48	11.7990	-0.0310	0.0370	0.0435
GRID	49	11.7990	-0.4460	0.5450	0.0341
GRID	50	11.7990	-0.8600	1.0540	0.0107
GRID	51	12.2500	0.3810	-0.4520	0.0082
GRID	52	12.2500	0.1830	-0.2180	0.0283

```
GRID          53          12.2500 -0.0140   0.0170   0.0336
GRID          54          12.2500 -0.2110   0.2510   0.0265
GRID          55          12.2500 -0.4080   0.4850   0.0066
```

Instructions for using PREBLASIM are given in section 2.1 of this manual. The interactive session as displayed on a computer screen when running PREBLASIM is listed below:

```
9-18-1992                                                       09:22:07

          BBBBBBB   LL         AAAAAA    SSSSSS   IIIIIIII  MM     MM
          BB    BB  LL        AA    AA  SS           II     MM MM MM
          BB    BB  LL        AA    AA  SS           II     MM MM MM
          BBBBBB    LL        AAAAAAAA   SSSSSS      II     MM MM MM
          BB    BB  LL        AA    AA        SS     II     MM     MM
          BB    BB  LL        AA    AA        SS     II     MM     MM
          BBBBBBB   LLLLLLLL  AA    AA   SSSSSS   IIIIIIII  MM     MM

                           Preprocessor for
                    BLades ASsessment for ice IMpact

          This Module Will Automatically Generate Input File for BLASIM
          Program. The Blade Geometry May be Defined in One of the
          Following Forms: a)Provide the Blade Finite Element Nodal
          Coordinates and their Thicknesses Thru a File, b)Supply the
          Airfoil Coordinates Thru a File, c)Select one of the Built-in
          NACA Airfoils. Any Wrong Entries or Defaulted Data May be
          Changed by Editing the Input File Created by the Program. To
          Find the Data Card Number, Variable Name and its Description,
          See Appendix A of the BLASIM User's Manual.

                    ....hit return to continue....


Summary of the Information Needed to Run the BLASIM Interactive
Program is Given Here:

|------------------------------------------------|-----------|
| Description of Entry                           | CARD #    |
|------------------------------------------------|-----------|
|  1. Definition of Blade Geometry, Choices are: |           |
|     a. Finite element coordinates & Thicknesses| A6a       |
|     b. Airfoil Coordinates & Stagger Angles    | A6,A7,A8  |
|     c. Construction of Blade With Built-in     | None      |
|        Airfoil Models                          |           |
|  2. Number of Blades & Operating Speed         | A10,A3    |
|  3. Blade Root Angle & Thickness, Broach Angle | A9        |
|  4. Option for Local & Root Ice Impact Analysis| B1a,B6b   |
|  5. Option for Flutter Analysis                | B1a,B3,B4 |
|  6. Option for Forcing Function Calculation    | B1a       |
|  7. Redline & Minimum Cruise Speeds            | B5        |
|  8. Number of Excitation Orders & Order Number | B5        |
|  9. Blade Type  & Elastic Material Properties  | B1a,B8,B11|
| 10. Pressure Data (Optional)                   | D2        |
| 11. Fatigue Life Data (Optional)               | E         |
|------------------------------------------------|-----------|

                    ....hit return to continue....


 Enter Title of the Problem :
SR2  Unswept  Titanium  Blade
```

The Terms in Bold are User's Entries

```
Blade Description and Analyses Options
--------------------------------------

This is  the First  Section of the Input File.  The Blade Geometry
Speed, and Analyses Options are Defined Here. The User is Expected
to Provide the  Blade  Finite Element Nodal or Airfoil Coordinates
Thru a Data File or Select an Airfoil Model to Construct the Blade.
See the User's Manual For More Details.

   Airfoil or Finite Element Input (A/F)? :F
   Enter format of the Grid coord. (x,y,z & thickness):24x,4f8.4
   Enter Geometry Filename :grid.dat
   Enter Number of Blades, and Blade Speed (rpm):8 4000

   Do You want to scale the Input Blade Thicknesses
   Along the Span (Enter Yes or No):n

   Enter Blade Description Starting Station # :2

   Do You Need Local Ice Impact Damage Analysis?
          (Enter Yes or No) :y
   Do You Need Root Ice Damage Analysis?
           (Enter Yes or No) :y
   Enter Ice Piece Length, Width, and Thickness (inches) :0.7 0.7 0.7
   Enter Ice Velocity (knots) :100

   Ice Density is Defaulted to 8.42E-05 (lb.sec**2/in**4)
   Enter Density Now or Hit Return to Accept Default Value:
   Enter Starting and Ending Ice Impact Location
   Along the Span as Fractions for Impact Modelling:0.5 0.9
   Enter the Number of Consecutive Ice Impacts
   (It Includes Geometry Update Following Each Impact):1

   Do You Need Flutter Analysis?
           (Enter Yes or No) :y
   Enter No. Roots Calculated by Flutter Analysis :5
   Enter Inlet Static Temperature (deg. F), and
   Inlet Static Pressure (lbf/ft**2) :32 2117
   Enter Relative Inlet Mach Number (> 1), and
   Corresponding radius (inches) :1.1 12.25

   Do You Need Resonance Margin Analysis?
           (Enter Yes or No) :y

   Do you Need Forcing Function Calculated?
           (Enter Yes or No) :y
   Enter Redline and Minimum Cruise Speeds (RPM) :4100 3900
   Enter Number of Excitation Orders (max. 5):3
   Enter 3 Excitation Order Nos. (1,2,3, etc.) :1 2 3


   Enter Code for Type of Blade Construction
   (0:solid; 1:hollow; 2:superhybrid; 3:composite :0

   Enter E11, E22, Nu12, G12, and Density
    for Solid Blade:16.5e06 16.5e06 0.3 6.34e06 0.00044


 Enter Ultimate Strengths (psi): Tension-11,
 Compression-11, Tension-22, Compression-22, and
 Shear-12   for Solid Blade:74000 74000 74000 74000 44400
```

```
The Blade Offsets are defined as..
  x = ACLX*Z + BCLX*Z**2 + CCLX*Z**3
  y = ACLY*Z + BCLY*Z**2 + CCLY*Z**3
where Z is spanwise variable
      y is chordwise variable
 and  x is transverse variable

The Offsets are Defaulted to Zero, to Accept the
Default Values Hit Return or Enter Now ACLX, BCLX,
CCLX, ACLY, BCLY, and CCLY:


Pressure Data
-------------

This is the Third Section of the Input File Where Pressure Loading
Data are Defined. If Pressure Loading is Applied, the User Has the
Option of Either Providing Data Thru a  File or Entering a Uniform
Pressure in This Section. Refer to the User's Manual for Details.

Is there Any Pressure Loading (Enter Yes or No):y

Will the Pressure Data Be Supplied Thru a Data File
            (Enter Yes or No) :n

The Pressure Entered Here is Uniform For All Elements
Enter the Value of the Element Pressure:5


Fatigue Life Data
-----------------

This Section of  the Input File is for Fatigue Data.   If Fatigue
Analysis is Desired, then Data  Such as Static and Dynamic  Stress
Limits are Entered Here.  Refer to the User's Manual for Details.

Do You Need to Enter Fatigue life Data for Forcing
Function Calculation? (Enter Yes or No):y
Enter Static and Dynamic Stress Limits (psi):75000 30000
Enter Multiple of Static Pressure:0
Enter Root Current, Reference, and Melting  Temperatures (F):100 100 2000
Enter the Exponent:1
Enter Forcing Function Factor: 1


Boundary Conditions Data
------------------------

Boundary  Conditions  Data Are  Defaulted,  i.e.,  All  Degrees of
Freedom at the Blade Root are Restrained.  To Change the Defaulted
Boundary Conditions, Refer to the User Manual, Section 2.0


The Input File Required to Run the BLASIM Code is  Generated
Under the Name BLASIM.INP. Use the Command or Job File Given
in the User's Manual to Run the Code on VAX or CRAY XMP.
```

The input file generated by PREBLASIM and used directly to run BLASIM is listed below:

```
SR2 Unswept Titanium Blade
NASTRAN GEOMETRY TYPE                                                   CARD A2
4000.0                         3.0   400.0                              CARD A3
1                                                          2.0          CARD A4
GRID         1          2.0600  0.0000 -0.4710  0.7267                  CARD A6a
GRID         2          2.0600  0.0000 -0.1980  1.0125                  CARD A6a
GRID         3          2.0600  0.0000  0.0000  1.0857                  CARD A6a
GRID         4          2.0600  0.0000  0.1980  1.0125                  CARD A6a
GRID         5          2.0600  0.0000  0.4710  0.7267                  CARD A6a
GRID         6          2.7780  0.0650 -0.5500  0.6666                  CARD A6a
GRID         7          2.7780  0.0510 -0.2190  0.7926                  CARD A6a
GRID         8          2.7780  0.0240 -0.0200  0.8927                  CARD A6a
GRID         9          2.7780 -0.0030  0.1980  0.8587                  CARD A6a
GRID        10          2.7780  0.0000  0.4710  0.7465                  CARD A6a
GRID        11          3.6840  0.4940 -1.5130  0.0990                  CARD A6a
GRID        12          3.6840  0.2030 -0.6550  0.2737                  CARD A6a
GRID        13          3.6840 -0.0540  0.1990  0.3339                  CARD A6a
GRID        14          3.6840 -0.2780  1.0540  0.2339                  CARD A6a
GRID        15          3.6840 -0.4710  1.9120  0.0774                  CARD A6a
GRID        16          5.0360  0.6530 -1.5240  0.0688                  CARD A6a
GRID        17          5.0360  0.2770 -0.6760  0.1804                  CARD A6a
GRID        18          5.0360 -0.0700  0.1680  0.2059                  CARD A6a
GRID        19          5.0360 -0.3900  1.0150  0.1343                  CARD A6a
GRID        20          5.0360 -0.6840  1.8630  0.0356                  CARD A6a
GRID        21          6.3890  0.7950 -1.5640  0.0486                  CARD A6a
GRID        22          6.3890  0.3580 -0.7400  0.1198                  CARD A6a
GRID        23          6.3890 -0.0450  0.0810  0.1447                  CARD A6a
GRID        24          6.3890 -0.4260  0.9020  0.1122                  CARD A6a
GRID        25          6.3890 -0.7760  1.7250  0.0340                  CARD A6a
GRID        26          7.7420  0.8840 -1.4970  0.0362                  CARD A6a
GRID        27          7.7420  0.4030 -0.7110  0.0891                  CARD A6a
GRID        28          7.7420 -0.0490  0.0750  0.1064                  CARD A6a
GRID        29          7.7420 -0.4800  0.8600  0.0835                  CARD A6a
GRID        30          7.7420 -0.8830  1.6460  0.0260                  CARD A6a
GRID        31          9.0940  0.9510 -1.4200  0.0285                  CARD A6a
GRID        32          9.0940  0.4400 -0.6750  0.0702                  CARD A6a
GRID        33          9.0940 -0.0500  0.0680  0.0837                  CARD A6a
GRID        34          9.0940 -0.5250  0.8120  0.0651                  CARD A6a
GRID        35          9.0940 -0.9780  1.5560  0.0207                  CARD A6a
GRID        36         10.4470  0.9680 -1.2870  0.0233                  CARD A6a
GRID        37         10.4470  0.4570 -0.6140  0.0575                  CARD A6a
GRID        38         10.4470 -0.0450  0.0570  0.0684                  CARD A6a
GRID        39         10.4470 -0.5400  0.7290  0.0533                  CARD A6a
GRID        40         10.4470 -1.0260  1.4020  0.0173                  CARD A6a
GRID        41         11.3480  0.8950 -1.1220  0.0193                  CARD A6a
GRID        42         11.3480  0.4270 -0.5380  0.0484                  CARD A6a
GRID        43         11.3480 -0.0370  0.0450  0.0576                  CARD A6a
GRID        44         11.3480 -0.4980  0.6290  0.0449                  CARD A6a
GRID        45         11.3480 -0.9550  1.2130  0.0148                  CARD A6a
GRID        46         11.7990  0.8050 -0.9800  0.0137                  CARD A6a
GRID        47         11.7990  0.3860 -0.4710  0.0366                  CARD A6a
GRID        48         11.7990 -0.0310  0.0370  0.0435                  CARD A6a
GRID        49         11.7990 -0.4460  0.5450  0.0341                  CARD A6a
GRID        50         11.7990 -0.8600  1.0540  0.0107                  CARD A6a
GRID        51         12.2500  0.3810 -0.4520  0.0082                  CARD A6a
GRID        52         12.2500  0.1830 -0.2180  0.0283                  CARD A6a
GRID        53         12.2500 -0.0140  0.0170  0.0336                  CARD A6a
GRID        54         12.2500 -0.2110  0.2510  0.0265                  CARD A6a
GRID        55         12.2500 -0.4080  0.4850  0.0066                  CARD A6a
             0.0    1.086   0.000     0.0                               CARD A9
```

```
                                                                    8.0          CARD A10
   5    3    5    0    1    1    2    0    1   1.02307    1                    CARD B1a
 .0001.0001.000                                                                  CARD B1b
 2  0.8927 5  0.1447 7  0.0837 9  0.057611  0.0336                              CARD B2
           32.00000                    1                                         CARD B3
   1.10000  12.25000        2117.00000                                           CARD B4
  4100.000  3900.000    3    1    2    3                                         CARD B5
   0.70000   0.70000   0.70000 100.00000  0.000084   0.00001   0.00000           CARD B6b
   0.50000   0.90000   16   40          1                                        CARD B7
 0.165E+08 0.165E+08   0.30000 0.634E+07  0.00044                                CARD B8
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000                                 CARD B9e
 0.740E+05 0.740E+05 0.740E+05 0.740E+05 0.444E+05 0.444E+05                     CARD B11
ELEMENT PRESSURE DATA
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
PRESSURE            5.00                                                         CARD D2
```

```
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
PRESSURE            5.00                                                   CARD D2
FATIGUE LIFE DATA
STATIC LIMIT     75000.0                                                   CARD E2
DYNAMIC LIMIT    30000.0                                                   CARD E3
MULTIPLE             0.0                                                   CARD E4
TMELT             2000.0                                                   CARD E5
TREF               100.0                                                   CARD E6
TCURRENT           100.0                                                   CARD E7
EXPONENT             1.0                                                   CARD E8
FORCE                1.0                                                   CARD E9
```

A.3 Output File (*Unit 30*)

The output file generated by BLASIM and containing static, modal, ice impact, flutter, and fatigue output is given here. BLASIM provides analysis information prior and following each impact. This capability shows to what extent the characteristics of the blade have been altered due to ice impact.

```
           BBBBBBB   LL          AAAAAA    SSSSSS   IIIIIIII  MM     MM
           BB    BB  LL         AA    AA  SS           II     MMM   MMM
           BB    BB  LL         AA    AA  SS           II     MM MM MM
           BBBBBB    LL         AAAAAAAA   SSSSSS      II     MM     MM
           BB    BB  LL         AA    AA        SS     II     MM     MM
           BB    BB  LL         AA    AA        SS     II     MM     MM
           BBBBBBB   LLLLLLLL   AA    AA   SSSSSS   IIIIIIII  MM     MM

                         BLade ASsessment for Ice iMpact


 * * * * Initial Blade Geometry * * * *

Grid #       X         Y          Z     Thickness
-------   -------   ------    ------   ---------
```

1	2.0600	0.0000	-0.4710	0.7267
2	2.0600	0.0000	-0.1980	1.0125
3	2.0600	0.0000	0.0000	1.0857
4	2.0600	0.0000	0.1980	1.0125
5	2.0600	0.0000	0.4710	0.7267
6	2.7780	0.0650	-0.5500	0.6666
7	2.7780	0.0510	-0.2190	0.7926
8	2.7780	0.0240	-0.0200	0.8927
9	2.7780	-0.0030	0.1980	0.8587
10	2.7780	0.0000	0.4710	0.7465
11	3.6840	0.4940	-1.5130	0.0990
12	3.6840	0.2030	-0.6550	0.2737
13	3.6840	-0.0540	0.1990	0.3339
14	3.6840	-0.2780	1.0540	0.2339
15	3.6840	-0.4710	1.9120	0.0774
16	5.0360	0.6530	-1.5240	0.0688
17	5.0360	0.2770	-0.6760	0.1804
18	5.0360	-0.0700	0.1680	0.2059
19	5.0360	-0.3900	1.0150	0.1343
20	5.0360	-0.6840	1.8630	0.0356
21	6.3890	0.7950	-1.5640	0.0486
22	6.3890	0.3580	-0.7400	0.1198
23	6.3890	-0.0450	0.0810	0.1447
24	6.3890	-0.4260	0.9020	0.1122
25	6.3890	-0.7760	1.7250	0.0340
26	7.7420	0.8840	-1.4970	0.0362
27	7.7420	0.4030	-0.7110	0.0891
28	7.7420	-0.0490	0.0750	0.1064
29	7.7420	-0.4800	0.8600	0.0835
30	7.7420	-0.8830	1.6460	0.0260
31	9.0940	0.9510	-1.4200	0.0285
32	9.0940	0.4400	-0.6750	0.0702
33	9.0940	-0.0500	0.0680	0.0837
34	9.0940	-0.5250	0.8120	0.0651
35	9.0940	-0.9780	1.5560	0.0207
36	10.4470	0.9680	-1.2870	0.0233
37	10.4470	0.4570	-0.6140	0.0575
38	10.4470	-0.0450	0.0570	0.0684
39	10.4470	-0.5400	0.7290	0.0533
40	10.4470	-1.0260	1.4020	0.0173
41	11.3480	0.8950	-1.1220	0.0193
42	11.3480	0.4270	-0.5380	0.0484
43	11.3480	-0.0370	0.0450	0.0576
44	11.3480	-0.4980	0.6290	0.0449
45	11.3480	-0.9550	1.2130	0.0148
46	11.7990	0.8050	-0.9800	0.0137
47	11.7990	0.3860	-0.4710	0.0366
48	11.7990	-0.0310	0.0370	0.0435
49	11.7990	-0.4460	0.5450	0.0341
50	11.7990	-0.8600	1.0540	0.0107
51	12.2500	0.3810	-0.4520	0.0082
52	12.2500	0.1830	-0.2180	0.0283
53	12.2500	-0.0140	0.0170	0.0336
54	12.2500	-0.2110	0.2510	0.0265
55	12.2500	-0.4080	0.4850	0.0066

```
** * * * *  Tip Displacements  * * * * *
  Untwist             -1.1088

  Uncamber            -0.3939
  Max Tip Extension    0.0123
  Max In Plane Displ   0.7026   0.1287
```

* * * * Resonance Margin Information * * * *

Frequencies At	4000.2 rpm	157.48	489.16	761.59
Frequencies At	4400.4 rpm	165.92	497.73	763.45

Red Line Speed-rpm = 4100.0 Min Cruise Speed-rpm = 3900.0

Frequency-cps (Red Line)	Frequency-cps (Min Cruise)	Margin (Red Line)	Margin (Min Cruise)	Margin (Max)	Excit. Order	Root Number
0.15955E+03	0.15543E+03	0.13349E+01	-0.13912E+01	0.13349E+01	1	1
0.15955E+03	0.15543E+03	0.16744E+00	-0.19560E+00	0.16744E+00	2	1
0.15955E+03	0.15543E+03	-0.22171E+00	0.20293E+00	0.20293E+00	3	1
0.49123E+03	0.48712E+03	0.61888E+01	-0.64941E+01	0.61888E+01	1	2
0.49123E+03	0.48712E+03	0.25944E+01	-0.27471E+01	0.25944E+01	2	2
0.49123E+03	0.48712E+03	0.13963E+01	-0.14980E+01	0.13963E+01	3	2
0.76204E+03	0.76115E+03	0.10152E+02	-0.10710E+02	0.10152E+02	1	3
0.76204E+03	0.76115E+03	0.45759E+01	-0.48550E+01	0.45759E+01	2	3
0.76204E+03	0.76115E+03	0.27172E+01	-0.29033E+01	0.27172E+01	3	3

* * * * * * * * * Forced Response Output * * * * * * * * *

* * * At Minimum Cruise Speed of 3900.0 rpm * * *

Root #	Order #	Steady Stress	Vibratory Stress	Allowed Vibratory Stress	PMGD
1	1	0.59837E+04	0.24555E+04	0.27607E+05	0.08895
1	2	0.59837E+04	0.20604E+04	0.27607E+05	0.07463
1	3	0.59837E+04	0.20366E+04	0.27607E+05	0.07377
2	1	0.23358E+04	0.22138E+04	0.29066E+05	0.07617
2	2	0.23358E+04	0.70496E+03	0.29066E+05	0.02425
2	3	0.23358E+04	0.67168E+03	0.29066E+05	0.02311
3	1	0.48133E+04	0.36208E+02	0.28075E+05	0.00129
3	2	0.48133E+04	0.25450E+02	0.28075E+05	0.00091
3	3	0.48133E+04	0.22648E+02	0.28075E+05	0.00081

* * * At Redline (Max.) Speed of 4100.0 rpm * * *

Root #	Order #	Steady Stress	Vibratory Stress	Allowed Vibratory Stress	PMGD
1	1	0.59837E+04	0.23549E+04	0.27607E+05	0.08530
1	2	0.59837E+04	0.19585E+04	0.27607E+05	0.07094
1	3	0.59837E+04	0.19341E+04	0.27607E+05	0.07006
2	1	0.23358E+04	0.24639E+04	0.29066E+05	0.08477
2	2	0.23358E+04	0.69798E+03	0.29066E+05	0.02401
2	3	0.23358E+04	0.66238E+03	0.29066E+05	0.02279
3	1	0.48133E+04	0.31913E+02	0.28075E+05	0.00114
3	2	0.48133E+04	0.25833E+02	0.28075E+05	0.00092
3	3	0.48133E+04	0.22749E+02	0.28075E+05	0.00081

Maximum Forced Responce Margins For Each Mode

Mode	Margin
1	0.0889
2	0.0848
3	0.0013

* * * * FLUTTER OUTPUT * * * *

NASA FLUTTER ANALYSIS

MODE	CRIT. NODAL DIA.	AERO. DAMPING COEF.
1	-1	0.75980E+02
2	1	0.27765E+02

3 3 0.13432E+03

```
* * * * STRESS OUTPUT * * * *

ROOT STRESS (PSI) =  0.59837E+04

NUMBER OF BLADES =  0.80000E+01

   -------------------------------------------------
   | Blade Analysis Due To The First    Ice Impact |
   -------------------------------------------------


* * * * Ice Impact Location * * * *

 Local Region Close To  50.00% Of The span Is At Radius =     7.742 inch
 Local Region Close To  90.00% Of The Span Is At Radius =    11.348 inch

 * * * * Ice Impact Analysis Local Coordinates and Thickness * * * *
```

Local Grid #	X	Y	Z	Thickness
1	7.7420	0.8840	-1.4970	0.0388
2	7.7420	0.6427	-1.1088	0.0718
3	7.7420	0.4068	-0.7174	0.0953
4	7.7420	0.1762	-0.3228	0.1094
5	7.7420	-0.0490	0.0750	0.1142
6	8.3425	0.9167	-1.4671	0.0334
7	8.3427	0.6681	-1.0866	0.0618
8	8.3428	0.4242	-0.7032	0.0821
9	8.3429	0.1847	-0.3169	0.0943
10	8.3429	-0.0501	0.0722	0.0983
11	8.9437	0.9447	-1.4303	0.0293
12	8.9437	0.6905	-1.0591	0.0543
13	8.9437	0.4400	-0.6855	0.0720
14	8.9438	0.1931	-0.3095	0.0827
15	8.9438	-0.0502	0.0689	0.0862
16	9.5455	0.9672	-1.3856	0.0264
17	9.5450	0.7092	-1.0258	0.0489
18	9.5447	0.4538	-0.6641	0.0649
19	9.5447	0.2011	-0.3004	0.0745
20	9.5447	-0.0491	0.0650	0.0776
21	10.1473	0.9744	-1.3258	0.0242
22	10.1463	0.7167	-0.9813	0.0449
23	10.1458	0.4606	-0.6354	0.0596
24	10.1456	0.2061	-0.2883	0.0684
25	10.1456	-0.0468	0.0601	0.0711
26	10.7480	0.9527	-1.2399	0.0220
27	10.7472	0.7026	-0.9177	0.0410
28	10.7467	0.4533	-0.5947	0.0544
29	10.7465	0.2048	-0.2709	0.0623
30	10.7465	-0.0428	0.0535	0.0648
31	11.3474	0.8951	-1.1221	0.0193
32	11.3474	0.6613	-0.8309	0.0363
33	11.3474	0.4281	-0.5393	0.0484
34	11.3474	0.1953	-0.2474	0.0555
35	11.3474	-0.0370	0.0450	0.0576

```
 * * * * Ice Impact Input and Derived Parameters * * * *

 Blade velocity at impact radius .....     3998.41 in/sec
 Ice velocity ........................     2025.37 in/sec    ( 100.00 knots)
 Ice equivalent radius ...............        0.43 inch
 Local impact reference node .........      16
```

```
Global corresponding impact node ....       31
Impact radius at reference node .....        9.55 inch
Impact angle ........................       28.12 degrees
Stagger angle .......................       54.99 degrees
Density .............................   0.840E-04 lbm.sec^2/in^4
```

** * * * Out-of-Plane Impact Displacements * * * *

Local Grid #	Displacement	Local Grid #	Displacement
1	0.000000	2	0.000000
3	0.000000	4	0.000000
5	0.000000	6	-0.004714
7	0.015953	8	0.018654
9	0.009488	10	0.000000
11	-0.014553	12	0.023231
13	0.031157	14	0.015600
15	0.000000	16	-0.021353
17	0.024818	18	0.041884
19	0.020296	20	0.000000
21	-0.021474	22	0.026737
23	0.043128	24	0.021075
25	0.000000	26	-0.016921
27	0.025133	28	0.031741
29	0.016112	30	0.000000
31	0.000000	32	0.000000
33	0.000000	34	0.000000
35	0.000000		

* * * * Local Ice Impact Output * * * *

```
Maximum Leading Edge Strain % .........  0.10370E+01
Time Of Occurence .....................  0.21000E-03
```

* * * * Updated Blade Geometry Due To The First   Ice Impact * * * *

Grid #	X	Y	Z	Thickness
1	2.0600	0.0000	-0.4710	0.7267
2	2.0600	0.0000	-0.1980	1.0125
3	2.0600	0.0000	0.0000	1.0857
4	2.0600	0.0000	0.1980	1.0125
5	2.0600	0.0000	0.4710	0.7267
6	2.7780	0.0650	-0.5500	0.6666
7	2.7780	0.0510	-0.2190	0.7926
8	2.7780	0.0240	-0.0200	0.8927
9	2.7780	-0.0030	0.1980	0.8587
10	2.7780	0.0000	0.4710	0.7465
11	3.6840	0.4940	-1.5130	0.2090
12	3.6840	0.2030	-0.6550	0.5779
13	3.6840	-0.0540	0.1990	0.7050
14	3.6840	-0.2780	1.0540	0.4939
15	3.6840	-0.4710	1.9120	0.1634
16	5.0360	0.6530	-1.5240	0.1420
17	5.0360	0.2770	-0.6760	0.3723
18	5.0360	-0.0700	0.1680	0.4250
19	5.0360	-0.3900	1.0150	0.2772
20	5.0360	-0.6840	1.8630	0.0735
21	6.3890	0.7950	-1.5640	0.0486
22	6.3890	0.3580	-0.7400	0.1198
23	6.3890	-0.0450	0.0810	0.1447

24	6.3890	-0.4260	0.9020	0.1122
25	6.3890	-0.7760	1.7250	0.0340
26	7.7420	0.8840	-1.4970	0.0388
27	7.7420	0.4030	-0.7110	0.0956
28	7.7420	-0.0490	0.0750	0.1142
29	7.7420	-0.4800	0.8600	0.0896
30	7.7420	-0.8830	1.6460	0.0279
31	9.0952	0.9377	-1.4292	0.0285
32	9.0927	0.4686	-0.6557	0.0702
33	9.0940	-0.0500	0.0680	0.0837
34	9.0940	-0.5250	0.8120	0.0651
35	9.0940	-0.9780	1.5560	0.0207
36	10.4481	0.9528	-1.2986	0.0232
37	10.4458	0.4870	-0.5915	0.0572
38	10.4470	-0.0450	0.0570	0.0680
39	10.4470	-0.5400	0.7290	0.0530
40	10.4470	-1.0260	1.4020	0.0172
41	11.3480	0.8950	-1.1220	0.0193
42	11.3480	0.4270	-0.5380	0.0484
43	11.3480	-0.0370	0.0450	0.0576
44	11.3480	-0.4980	0.6290	0.0449
45	11.3480	-0.9550	1.2130	0.0148
46	11.7990	0.8050	-0.9800	0.0144
47	11.7990	0.3860	-0.4710	0.0384
48	11.7990	-0.0310	0.0370	0.0456
49	11.7990	-0.4460	0.5450	0.0357
50	11.7990	-0.8600	1.0540	0.0112
51	12.2500	0.3810	-0.4520	0.0082
52	12.2500	0.1830	-0.2180	0.0283
53	12.2500	-0.0140	0.0170	0.0336
54	12.2500	-0.2110	0.2510	0.0265
55	12.2500	-0.4080	0.4850	0.0066

```
* * * * Root Ice Impact output * * * *

Root ice impact response (Mod. dist. crit.)          0.001
At element number  ........................     15
At layer number ...........................      1

** * * * *  Tip Displacements  * * * * *

  Untwist             -0.5961
  Uncamber            -0.8136
  Max Tip Extension    0.0106
  Max In Plane Displ   0.6185  0.1189


* * * * Resonance Margin Information * * * *

Frequencies At  4000.2 rpm     159.07    518.40    759.46
Frequencies At  4400.4 rpm     167.29    526.10    761.30

Red Line Speed-rpm =  4100.0   Min Cruise Speed-rpm =  3900.0
```

Frequency-cps (Red Line)	Frequency-cps (Min Cruise)	Margin (Red Line)	Margin (Min Cruise)	Margin (Max)	Excit. Order	Root Number
0.16108E+03	0.15707E+03	0.13573E+01	-0.14165E+01	0.13573E+01	1	1
0.16108E+03	0.15707E+03	0.17867E+00	-0.20825E+00	0.17867E+00	2	1
0.16108E+03	0.15707E+03	-0.21422E+00	0.19450E+00	0.19450E+00	3	1
0.52026E+03	0.51657E+03	0.66136E+01	-0.69472E+01	0.66136E+01	1	2
0.52026E+03	0.51657E+03	0.28068E+01	-0.29736E+01	0.28068E+01	2	2
0.52026E+03	0.51657E+03	0.15379E+01	-0.16491E+01	0.15379E+01	3	2
0.75990E+03	0.75902E+03	0.10120E+02	-0.10677E+02	0.10120E+02	1	3

0.75990E+03	0.75902E+03	0.45602E+01	-0.48386E+01	0.45602E+01	2	3
0.75990E+03	0.75902E+03	0.27068E+01	-0.28924E+01	0.27068E+01	3	3

* * * * * * * * * Forced Response Output * * * * * * * * *

* * * At Minimum Cruise Speed of 3900.0 rpm * * *

Root #	Order #	Steady Stress	Vibratory Stress	Allowed Vibratory Stress	PMGD
1	1	0.59757E+04	0.25063E+04	0.27610E+05	0.09078
1	2	0.59757E+04	0.21080E+04	0.27610E+05	0.07635
1	3	0.59757E+04	0.20881E+04	0.27610E+05	0.07563
2	1	0.23320E+04	0.21161E+04	0.29067E+05	0.07280
2	2	0.23320E+04	0.70120E+03	0.29067E+05	0.02412
2	3	0.23320E+04	0.67406E+03	0.29067E+05	0.02319
3	1	0.48062E+04	0.89648E+02	0.28078E+05	0.00319
3	2	0.48062E+04	0.58194E+02	0.28078E+05	0.00207
3	3	0.48062E+04	0.52939E+02	0.28078E+05	0.00189

* * * At Redline (Max.) Speed of 4100.0 rpm * * *

Root #	Order #	Steady Stress	Vibratory Stress	Allowed Vibratory Stress	PMGD
1	1	0.59757E+04	0.24085E+04	0.27610E+05	0.08723
1	2	0.59757E+04	0.20073E+04	0.27610E+05	0.07270
1	3	0.59757E+04	0.19867E+04	0.27610E+05	0.07196
2	1	0.23320E+04	0.23522E+04	0.29067E+05	0.08092
2	2	0.23320E+04	0.69562E+03	0.29067E+05	0.02393
2	3	0.23320E+04	0.66645E+03	0.29067E+05	0.02293
3	1	0.48062E+04	0.78288E+02	0.28078E+05	0.00279
3	2	0.48062E+04	0.58967E+02	0.28078E+05	0.00210
3	3	0.48062E+04	0.53177E+02	0.28078E+05	0.00189

Maximum Forced Responce Margins For Each Mode

Mode	Margin
1	0.0908
2	0.0809
3	0.0032

* * * * FLUTTER OUTPUT * * * *

NASA FLUTTER ANALYSIS

MODE	CRIT. NODAL DIA.	AERO. DAMPING COEF.
1	-1	0.44625E+02
2	0	0.84673E+01
3	3	0.14345E+03

* * * * STRESS OUTPUT * * * *

ROOT STRESS (PSI) = 0.59757E+04

NUMBER OF BLADES = 0.80000E+01

A.4 Modal Analysis Results (Unit 45)

The modal analysis results are written to a file on logical unit 45. These data can be used to evaluate the mode shapes for pre-and-post-ice impact conditions. A listing of the modal analysis output file is given in this section. For each mode, the natural frequency and the global modal displacements T1, T2, and T3 (i.e. u, v, and w) are provided. The modal output file for the example used in this appendix is listed below:

```
MODAL PRINT FOR ROOT NUMBER  1      FREQUENCY (CPS)=  0.15748E+03
       GRID #              T1         T2        T3          PRE-IMPACT
            1          0.00000 0.00000 0.00000
            2          0.00000 0.00000 0.00000
            3          0.00000 0.00000 0.00000
            4          0.00000 0.00000 0.00000
            5          0.00000 0.00000 0.00000
            6         -0.00002 0.00012 0.00000
            7         -0.00002 0.00015 0.00000
            8          0.00000 0.00015 0.00000
            9          0.00001 0.00015-0.00001
           10          0.00001 0.00014-0.00001
           11         -0.00046 0.00047-0.00015
           12         -0.00016 0.00091 0.00000
           13          0.00006 0.00097 0.00002
           14          0.00021 0.00072-0.00006
           15          0.00028 0.00017-0.00018
           16         -0.00093 0.00374 0.00043
           17         -0.00031 0.00444 0.00071
           18          0.00014 0.00435 0.00066
           19          0.00045 0.00373 0.00045
           20          0.00066 0.00269 0.00010
           21         -0.00254 0.01407 0.00343
           22         -0.00072 0.01586 0.00467
           23          0.00029 0.01570 0.00461
           24          0.00087 0.01300 0.00332
           25          0.00092 0.00720 0.00087
           26         -0.00876 0.07407 0.03113
           27         -0.00323 0.08015 0.03475
           28          0.00073 0.07574 0.03221
           29          0.00342 0.06246 0.02503
           30          0.00364 0.03740 0.01225
           31         -0.02219 0.23290 0.11633
           32         -0.00945 0.23361 0.11694
           33          0.00137 0.22121 0.10869
           34          0.01008 0.19369 0.09102
           35          0.01514 0.15449 0.06715
           36         -0.03997 0.48077 0.26241
           37         -0.01861 0.47185 0.25557
           38          0.00170 0.45284 0.24129
           39          0.02028 0.42070 0.21758
           40          0.03639 0.37607 0.18536
           41         -0.04677 0.68560 0.39000
           42         -0.02222 0.66896 0.37664
           43          0.00153 0.65069 0.36209
           44          0.02440 0.62103 0.33868
           45          0.04630 0.58718 0.31221
           46         -0.04640 0.78782 0.45365
           47         -0.02240 0.77290 0.44137
           48          0.00128 0.75516 0.42682
           49          0.02445 0.73028 0.40648
           50          0.04716 0.70077 0.38248
```

51	-0.02410	0.87958	0.50825
52	-0.01172	0.87098	0.50099
53	0.00020	0.86136	0.49292
54	0.01228	0.85127	0.48445
55	0.02438	0.83963	0.47464

MODAL PRINT FOR ROOT NUMBER 2 FREQUENCY (CPS)= 0.48916E+03

GRID #	T1	T2	T3 *PRE-IMPACT*
1	0.00000	0.00000	0.00000
2	0.00000	0.00000	0.00000
3	0.00000	0.00000	0.00000
4	0.00000	0.00000	0.00000
5	0.00000	0.00000	0.00000
6	0.00036	-0.00067	0.00021
7	0.00020	-0.00081	0.00021
8	0.00002	-0.00084	0.00018
9	-0.00018	-0.00085	0.00022
10	-0.00028	-0.00078	0.00024
11	0.00355	-0.00307	0.00149
12	0.00128	-0.00493	0.00082
13	-0.00051	-0.00532	0.00072
14	-0.00193	-0.00447	0.00097
15	-0.00307	-0.00239	0.00144
16	0.00589	-0.01968	-0.00020
17	0.00228	-0.02182	-0.00116
18	-0.00087	-0.02170	-0.00120
19	-0.00342	-0.02030	-0.00066
20	-0.00534	-0.01729	0.00044
21	0.01161	-0.06629	-0.01398
22	0.00435	-0.06402	-0.01324
23	-0.00117	-0.06463	-0.01347
24	-0.00562	-0.06055	-0.01157
25	-0.00826	-0.05614	-0.01006
26	0.02542	-0.20986	-0.07675
27	0.01014	-0.19204	-0.06597
28	-0.00218	-0.18586	-0.06269
29	-0.01264	-0.18432	-0.06169
30	-0.01988	-0.17938	-0.05888
31	0.03761	-0.37512	-0.15559
32	0.01572	-0.32231	-0.11872
33	-0.00262	-0.32024	-0.11688
34	-0.02122	-0.34357	-0.13163
35	-0.04402	-0.42074	-0.17897
36	0.01638	-0.16401	0.01891
37	0.00696	-0.13698	0.03912
38	-0.00201	-0.15109	0.02837
39	-0.01323	-0.20771	-0.01312
40	-0.02916	-0.31198	-0.08805
41	-0.00785	0.21035	0.31284
42	-0.00440	0.21306	0.31483
43	-0.00160	0.19093	0.29717
44	-0.00046	0.12044	0.24143
45	-0.00265	0.01442	0.15853
46	-0.01929	0.44082	0.49442
47	-0.01041	0.44327	0.49626
48	-0.00144	0.41674	0.47443
49	0.00626	0.35143	0.42102
50	0.01195	0.25415	0.34216
51	-0.01665	0.71077	0.70819
52	-0.00880	0.69860	0.69792
53	-0.00216	0.67750	0.68017
54	0.00494	0.65270	0.65941
55	0.01186	0.61818	0.63036

MODAL PRINT FOR ROOT NUMBER 3 FREQUENCY (CPS)= 0.76159E+03

GRID # T1 T2 T3 *PRE-IMPACT*

```
             1          0.00000 0.00000 0.00000
             2          0.00000 0.00000 0.00000
             3          0.00000 0.00000 0.00000
             4          0.00000 0.00000 0.00000
             5          0.00000 0.00000 0.00000
             6          0.00016 0.00007 0.00011
             7          0.00004-0.00011 0.00011
             8         -0.00006-0.00021 0.00010
             9         -0.00010-0.00032 0.00010
            10         -0.00010-0.00044 0.00011
            11          0.00157 0.00232 0.00160
            12          0.00043-0.00003 0.00076
            13         -0.00031-0.00175 0.00031
            14         -0.00071-0.00322-0.00001
            15         -0.00093-0.00474-0.00033
            16          0.00196 0.00462 0.00454
            17          0.00051-0.00083 0.00229
            18         -0.00076-0.00622 0.00003
            19         -0.00154-0.01107-0.00180
            20         -0.00174-0.01427-0.00272
            21          0.00354 0.03480 0.02534
            22          0.00022 0.00487 0.00757
            23         -0.00207-0.01516-0.00168
            24         -0.00314-0.03410-0.00992
            25         -0.00211-0.06158-0.02389
            26         -0.00198 0.15977 0.10590
            27         -0.00292 0.06568 0.04925
            28         -0.00553-0.02289-0.00243
            29         -0.00723-0.10338-0.04761
            30         -0.00752-0.18413-0.08829
            31         -0.02088 0.49142 0.35050
            32         -0.00946 0.18971 0.13862
            33         -0.01044-0.01118 0.00749
            34         -0.01227-0.19509-0.10826
            35         -0.02683-0.45654-0.27181
            36         -0.01776 0.56023 0.43906
            37         -0.01571 0.26403 0.21614
            38         -0.01551-0.02659-0.00141
            39         -0.01812-0.27463-0.18478
            40         -0.01525-0.42590-0.29263
            41         -0.02837 0.76944 0.63851
            42         -0.01787 0.27606 0.24139
            43         -0.02064-0.09531-0.05182
            44         -0.02427-0.41860-0.30483
            45         -0.03800-0.76126-0.57546
            46         -0.02316 0.64933 0.55859
            47         -0.01935 0.22027 0.20913
            48         -0.02136-0.15321-0.09551
            49         -0.02853-0.48293-0.36291
            50         -0.03811-0.76599-0.58968
            51         -0.02063 0.17390 0.18158
            52         -0.01938-0.02689 0.01380
            53         -0.02238-0.22158-0.14692
            54         -0.02563-0.41094-0.30391
            55         -0.03388-0.58416-0.44748
MODAL PRINT FOR ROOT NUMBER  1      FREQUENCY (CPS)=  0.15907E+03
       GRID #             T1        T2        T3      POST-IMPACT
             1          0.00000 0.00000 0.00000
             2          0.00000 0.00000 0.00000
             3          0.00000 0.00000 0.00000
             4          0.00000 0.00000 0.00000
             5          0.00000 0.00000 0.00000
             6         -0.00002 0.00013 0.00000
             7         -0.00002 0.00016 0.00000
```

```
                8         0.00000 0.00016 0.00000
                9         0.00002 0.00016-0.00001
               10         0.00001 0.00015-0.00001
               11        -0.00049 0.00050-0.00017
               12        -0.00017 0.00098 0.00000
               13         0.00007 0.00105 0.00002
               14         0.00022 0.00078-0.00006
               15         0.00029 0.00019-0.00020
               16        -0.00100 0.00403 0.00046
               17        -0.00034 0.00478 0.00076
               18         0.00016 0.00469 0.00071
               19         0.00049 0.00403 0.00048
               20         0.00070 0.00292 0.00011
               21        -0.00269 0.01492 0.00357
               22        -0.00079 0.01711 0.00503
               23         0.00033 0.01692 0.00496
               24         0.00094 0.01410 0.00362
               25         0.00097 0.00804 0.00109
               26        -0.00930 0.08053 0.03372
               27        -0.00372 0.08732 0.03792
               28         0.00085 0.08201 0.03495
               29         0.00381 0.06869 0.02772
               30         0.00413 0.04319 0.01469
               31        -0.01981 0.24203 0.12077
               32        -0.01525 0.24573 0.12258
               33         0.00185 0.23708 0.11604
               34         0.01103 0.21040 0.09886
               35         0.01648 0.16993 0.07428
               36        -0.03594 0.49683 0.26850
               37        -0.02626 0.49247 0.26595
               38         0.00265 0.47931 0.25526
               39         0.02168 0.44643 0.23102
               40         0.03794 0.39603 0.19461
               41        -0.04645 0.69514 0.39025
               42        -0.02079 0.68151 0.37929
               43         0.00269 0.67299 0.37250
               44         0.02574 0.64626 0.35134
               45         0.04789 0.61059 0.32351
               46        -0.04513 0.78758 0.44532
               47        -0.02092 0.78019 0.43947
               48         0.00249 0.77270 0.43337
               49         0.02569 0.75192 0.41632
               50         0.04844 0.72196 0.39187
               51        -0.02266 0.88366 0.50351
               52        -0.01029 0.87931 0.49993
               53         0.00147 0.87396 0.49542
               54         0.01347 0.86729 0.48978
               55         0.02562 0.85729 0.48132
MODAL PRINT FOR ROOT NUMBER  2     FREQUENCY (CPS)=  0.51840E+03
        GRID #              T1      T2      T3      POST-IMPACT
                1         0.00000 0.00000 0.00000
                2         0.00000 0.00000 0.00000
                3         0.00000 0.00000 0.00000
                4         0.00000 0.00000 0.00000
                5         0.00000 0.00000 0.00000
                6         0.00045-0.00079 0.00027
                7         0.00024-0.00096 0.00026
                8         0.00003-0.00099 0.00023
                9        -0.00021-0.00099 0.00027
               10        -0.00035-0.00091 0.00030
               11         0.00424-0.00376 0.00177
               12         0.00154-0.00582 0.00102
               13        -0.00060-0.00621 0.00092
               14        -0.00232-0.00516 0.00122
```

```
                 15        -0.00374-0.00269 0.00177
                 16         0.00697-0.02326-0.00018
                 17         0.00272-0.02552-0.00119
                 18        -0.00099-0.02521-0.00118
                 19        -0.00405-0.02342-0.00049
                 20        -0.00642-0.01987 0.00080
                 21         0.01326-0.07627-0.01569
                 22         0.00511-0.07392-0.01485
                 23        -0.00117-0.07410-0.01491
                 24        -0.00650-0.06870-0.01246
                 25        -0.01016-0.06387-0.01060
                 26         0.02803-0.22966-0.08280
                 27         0.01080-0.21241-0.07179
                 28        -0.00176-0.20263-0.06588
                 29        -0.01372-0.19637-0.06218
                 30        -0.02275-0.19032-0.05883
                 31         0.04321-0.43497-0.17827
                 32         0.01808-0.34544-0.12530
                 33        -0.00034-0.31907-0.10696
                 34        -0.02124-0.33577-0.11799
                 35        -0.04765-0.42721-0.17351
                 36         0.03056-0.26494-0.03703
                 37         0.00389-0.13760 0.04767
                 38         0.00280-0.10979 0.07131
                 39        -0.01099-0.16269 0.03285
                 40        -0.03148-0.29721-0.06402
                 41         0.00419 0.06815 0.21481
                 42         0.00767 0.16339 0.29090
                 43         0.00494 0.22326 0.33819
                 44         0.00289 0.18346 0.30612
                 45        -0.00163 0.07431 0.22131
                 46        -0.00481 0.28541 0.38313
                 47         0.00120 0.38576 0.46644
                 48         0.00549 0.44358 0.51388
                 49         0.01051 0.41678 0.49142
                 50         0.01341 0.31972 0.41203
                 51        -0.00554 0.65371 0.67988
                 52         0.00075 0.68523 0.70681
                 53         0.00531 0.70119 0.71987
                 54         0.01090 0.70638 0.72385
                 55         0.01739 0.68969 0.70944
MODAL PRINT FOR ROOT NUMBER  3      FREQUENCY (CPS)=   0.75946E+03
       GRID #                 T1        T2        T3       POST-IMPACT
                  1         0.00000 0.00000 0.00000
                  2         0.00000 0.00000 0.00000
                  3         0.00000 0.00000 0.00000
                  4         0.00000 0.00000 0.00000
                  5         0.00000 0.00000 0.00000
                  6         0.00025-0.00012 0.00014
                  7         0.00010-0.00035 0.00014
                  8        -0.00005-0.00046 0.00012
                  9        -0.00013-0.00056 0.00013
                 10        -0.00015-0.00067 0.00015
                 11         0.00250 0.00140 0.00193
                 12         0.00077-0.00144 0.00091
                 13        -0.00044-0.00327 0.00042
                 14        -0.00119-0.00453 0.00016
                 15        -0.00169-0.00551-0.00004
                 16         0.00355-0.00107 0.00427
                 17         0.00115-0.00696 0.00181
                 18        -0.00097-0.01234-0.00047
                 19        -0.00246-0.01694-0.00220
                 20        -0.00320-0.01948-0.00287
                 21         0.00689 0.01419 0.01986
```

22	0.00143-0.01164 0.00415
23	-0.00239-0.03197-0.00512
24	-0.00461-0.05034-0.01300
25	-0.00454-0.07803-0.02712
26	0.00367 0.11950 0.09278
27	-0.00075 0.03562 0.04220
28	-0.00634-0.05240-0.00959
29	-0.00922-0.13111-0.05403
30	-0.01064-0.21103-0.09432
31	-0.01139 0.48411 0.34378
32	-0.01125 0.16245 0.14397
33	-0.01176-0.03577 0.00367
34	-0.01410-0.22039-0.11235
35	-0.03024-0.48931-0.28045
36	-0.01321 0.61937 0.48174
37	-0.01872 0.25440 0.24318
38	-0.01688-0.03426 0.00637
39	-0.01969-0.28852-0.18121
40	-0.01685-0.44046-0.28938
41	-0.02677 0.76262 0.64777
42	-0.01826 0.28840 0.26582
43	-0.02190-0.08267-0.02714
44	-0.02557-0.41766-0.28963
45	-0.03915-0.76656-0.56524
46	-0.02304 0.65950 0.58150
47	-0.02029 0.24984 0.24762
48	-0.02256-0.12253-0.05625
49	-0.02929-0.46370-0.33324
50	-0.03865-0.75937-0.57036
51	-0.02264 0.23394 0.24501
52	-0.02102 0.03405 0.07788
53	-0.02356-0.16377-0.08585
54	-0.02628-0.35771-0.24679
55	-0.03405-0.53717-0.39571

The blade and the first three natural mode shapes before and after first ice impact are shown in Figures A.2 and A.3 respectively. As described earlier in Section 2.0, the finite element mesh of the blade consists of 11 spanwise and 5 chordwise stations. However, for the sake of clarity, 21x9 grid lines are shown in the mode shapes after interpolation of modal displacements.

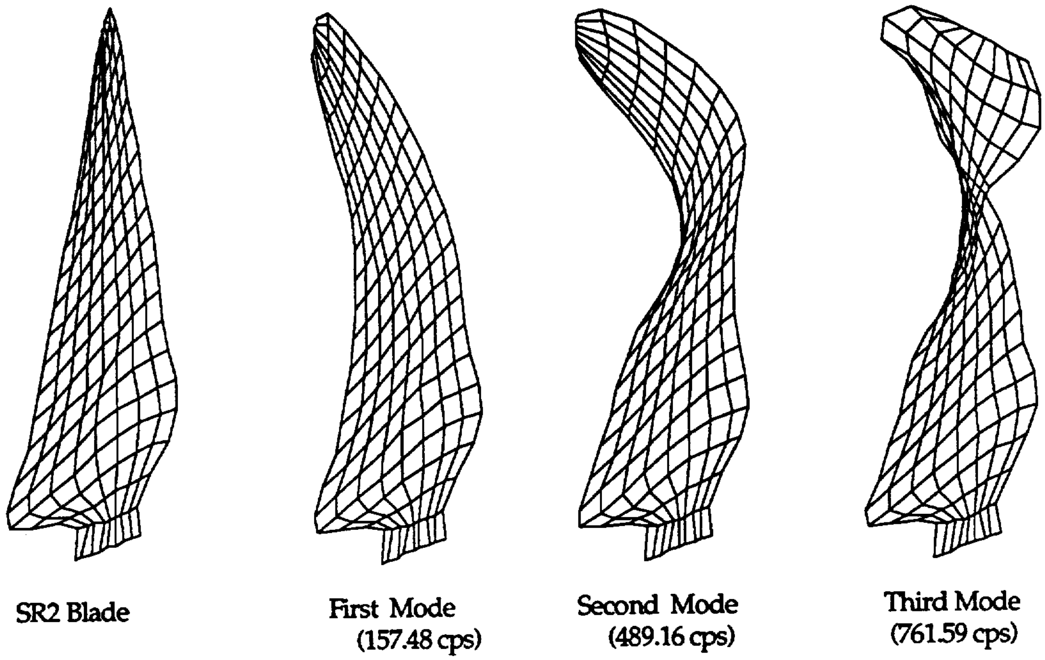


Figure A.2 Results of Dynamic Analysis from SR2 Titanium Blade Prior to Ice Impact

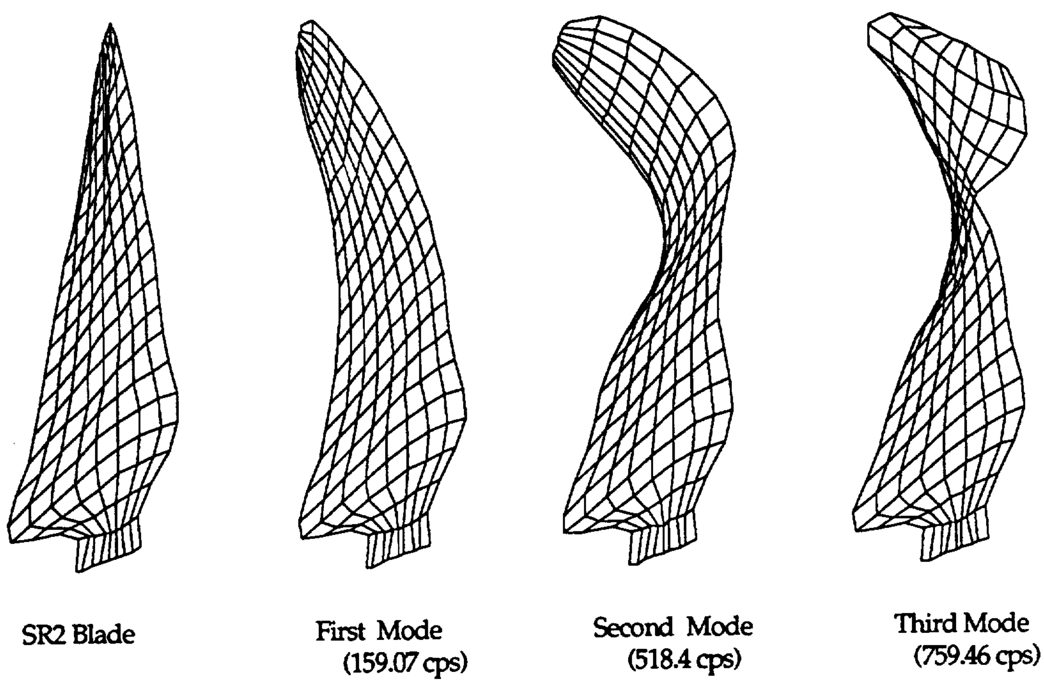


Figure A.3 Results of Dynamic Analysis from SR2 Titanium Blade After First Ice Impact

A.5 Parametric Study

For the SR-2 unswept titanium blade, parametric study is performed at 4000 rpm by varying ice speed. The average leading edge strain and the impact angle (relative to the chord) are plotted as a function of the ice speed in the Figure A.2.

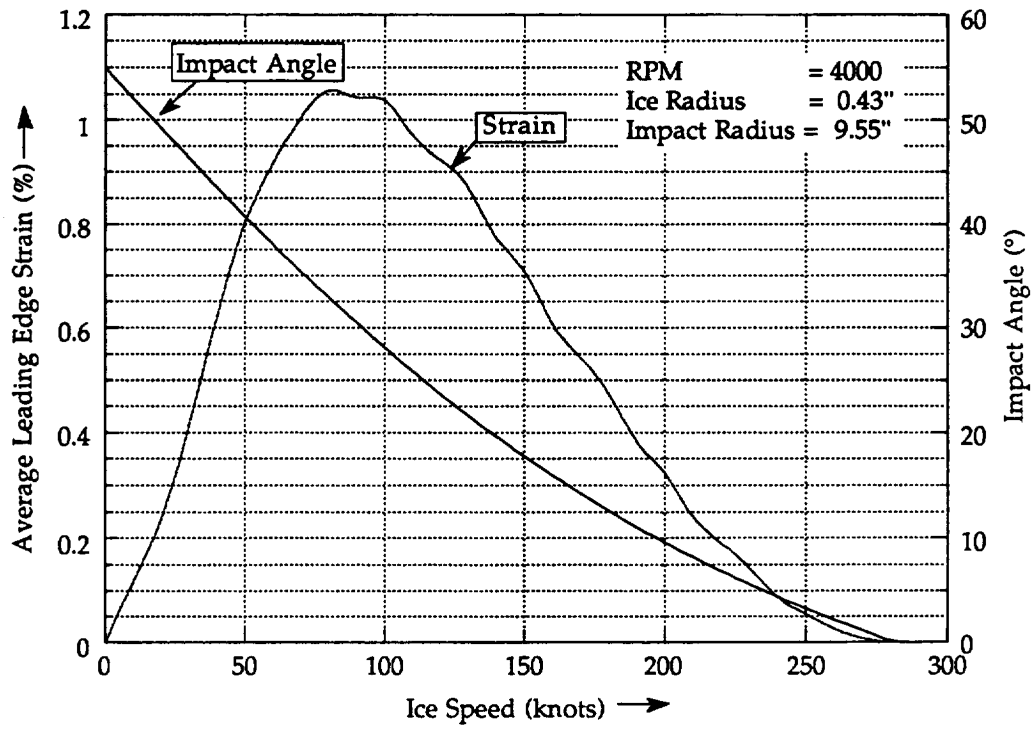


Figure A.4 Variation of Average Leading Edge Strain and Impact Angle with Ice Speed

APPENDIX B

FIBER-MATRIX OPTION USAGE

B.1 Introduction

For the composite blade, the ply properties can be input directly or determined based on the given fiber-matrix combination. In this appendix, the usage of the fiber-matrix option is demonstrated. BLASIM uses ICAN (Integrated Composite ANalyzer) to generate the ply properties. The material properties of fiber and matrices are picked from a dedicated Data Bank (See Section B.4). This data base reduces the burden on the user in preparing the necessary data for the constituent properties.

An SR2 composite blade is used to demonstrate the usage of ICAN. The blade is subjected to centrifugal load of 4000 rpm and uniform pressure of 3 psi. The ice impact conditions are the same as those used in Section A.1. Three fibers and matrices combinations are entered with keywords as described in the table below:

Material	*Keyword*
Titanium Fiber	TITF
Graphite Fiber	T300
Titanium matrix	TIT6
Epoxy Matrix	EPOC

B.2 Interactive Session

The BLASIM interactive input generator, PREBLASIM, is used to create the input file for this demonstration case. The finite element grid file used here is the same as the one listed in Section A.2. The interactive session as displayed on a computer screen when running PREBLASIM is listed below:

```
BBBBBBB    LL          AAAAAA    SSSSSS    IIIIIIII  MM     MM
BB     BB  LL        AA     AA  SS            II     MM MM  MM
BB     BB  LL        AA     AA  SS            II     MM MM  MM
BBBBBB     LL        AAAAAAAA    SSSSSS       II     MM MM  MM
BB     BB  LL        AA     AA        SS      II     MM     MM
BB     BB  LL        AA     AA        SS      II     MM     MM
BBBBBBB    LLLLLLLL  AA     AA   SSSSSS    IIIIIIII  MM     MM

                       Preprocessor for
                BLades ASsessment for ice IMpact

This Module Will Automatically Generate Input File for BLASIM
Program.  The  Blade  Geometry May  be  Defined in One of the
Following Forms:  a)Provide  the  Blade Finite Element  Nodal
Coordinates  and their Thicknesses Thru a File,  b)Supply the
Airfoil Coordinates Thru a File, c)Select one of the Built-in
NACA Airfoils.  Any  Wrong  Entries  or Defaulted Data May be
Changed by Editing the Input File Created  by the Program. To
```

Find the Data Card Number, Variable Name and its Description,
See Appendix A of the BLASIM User's Manual.

....hit return to continue....

Summary of the Information Needed to Run the BLASIM Interactive Program is Given Here:

Description of Entry	CARD #
1. Definition of Blade Geometry, Choices are:	
a. Finite element coordinates & Thicknesses	A6a
b. Airfoil Coordinates & Stagger Angles	A6,A7,A8
c. Construction of Blade With Built-in Airfoil Models	None
2. Number of Blades & Operating Speed	A10,A3
3. Blade Root Angle & Thickness, Broach Angle	A9
4. Option for Local & Root Ice Impact Analysis	B1a,B6b
5. Option for Flutter Analysis	B1a,B3,B4
6. Option for Forcing Function Calculation	B1a
7. Redline & Minimum Cruise Speeds	B5
8. Number of Excitation Orders & Order Number	B5
9. Blade Type & Elastic Material Properties	B1a,B8,B11
10. Pressure Data (Optional)	D2
11. Fatigue Life Data (Optional)	E

....hit return to continue....

Enter Title of the Problem :
SR2 Modified Composite Blade

The Terms in Bold are User's Entries

Blade Description and Analyses Options

This is the First Section of the Input File. The Blade Geometry Speed, and Analyses Options are Defined Here. The User is Expected to Provide the Blade Finite Element Nodal or Airfoil Coordinates Thru a Data File or Select an Airfoil Model to Construct the Blade. See the User's Manual For More Details.

Airfoil or Finite Element Input (A/F)? :**f**
Enter format of the Grid coord. (x,y,z & thickness):**24x,4f8.4**
Enter Geometry Filename :**grid.dat**
Enter Number of Blades, and Blade Speed (rpm):**8 4000**

Do You want to scale the Input Blade Thicknesses
Along the Span (Enter Yes or No):**n**

Enter Blade Description Starting Station # :**2**

Do You Need Local Ice Impact Damage Analysis?
(Enter Yes or No) :**y**
Do You Need Root Ice Damage Analysis?
(Enter Yes or No) :**y**
Enter Ice Piece Length, Width, and Thickness (inches) :**0.7 0.7 0.7**
Enter Ice Velocity (knots) :**100**

Ice Density is Defaulted to 8.42E-05 (lb.sec**2/in**4)

```
Enter Density Now or Hit Return to Accept Default Value:
Enter Starting and Ending Ice Impact Location
Along the Span as Fractions for Impact Modelling:0.5 0.9

Enter the Number of Consecutive Ice Impacts
(It Includes Geometry Update Following Each Impact):1
Do You Need Flutter Analysis?
         (Enter Yes or No) :y
Enter No. Roots Calculated by Flutter Analysis :5
Enter Inlet Static Temperature (deg. F), and
Inlet Static Pressure (lbf/ft**2) :32 2117
Enter Relative Inlet Mach Number (> 1), and
Corresponding radius (inches) :1.1 12.25
Do You Need Resonance Margin Analysis?
         (Enter Yes or No) :y
Do you Need Forcing Function Calculated?
         (Enter Yes or No) :y
Enter Redline and Minimum Cruise Speeds (RPM) :4200 3800
Enter Number of Excitation Orders (max. 5):3
Enter 3 Excitation Order Nos. (1,2,3, etc.) :1 2 3

Enter Code for Type of Blade Construction
(0:solid; 1:hollow; 2:superhybrid; 3:composite):3

Enter No. of Materials (max.: 7) :3

 For Composite Blade Option in BLASIM, Select One of the
 Following:

      1. Supply Material Elastic Properties
 or   2. Generate Material Elastic Properties Using ICAN
         (Integrated Composite ANalyzer) Based on Specified
         Fiber and Matrix

 Enter Choice:2

The Table Below Lists the Fiber and Matrix Types Available
in the ICAN Data Bank. The Properties for Each Composite will
be Determined Based on the Selected Fiber/Matrix Combinations.
```

Fiber Keyword & Description	Matrix Keyword & Description
T300 Graphite	EPOC Epoxy
P100 Graphite (High Modulus)	IMLS Inter. Mod. Low Str.
HMSF Surface Fiber (High Mod.)	IMHS Inter. Mod. High Str.
SGLA S-Glass	HMHS High Mod. High Str.
EGLA E-Glass	POLY Polyimide
SW4M Stainless Steel Wire	SSLA Stainless Steel
TITF Titanium	TIT6 Titanium
TUNG Tungsten	FECR Superalloy
SICA Silicon Carbide on Alum.	ALTX Aluminum
BOR5 Boron (5 Mil. Diameter)	BORM Boron
Note: Keywords for Fiber and Matrix Can be Entered in Lower or Upper Case.	

```
Enter Keyword for the Fiber for Material # 1:t300
Enter Keyword for the Matrix for Material # 1:tit6
Enter the Fiber Volume Ratio for Material # 1:0.4
Enter the Void Volume Ratio for Material # 1:0
Enter the Use and Cure Temperatures for Material # 1:70 70
Enter the Percentage of Moisture Content by Weight for
Material # 1: 0.0

Enter Keyword for the Fiber for Material # 2:t300
Enter Keyword for the Matrix for Material # 2:epoc
Enter the Fiber Volume Ratio for Material # 2:0.4
Enter the Void Volume Ratio for Material # 2:0
Enter the Use and Cure Temperatures for Material # 2:70 70
Enter the Percentage of Moisture Content by Weight for
Material # 2: 0.0

Enter Keyword for the Fiber for Material # 3:titf
Enter Keyword for the Matrix for Material # 3:tit6
Enter the Fiber Volume Ratio for Material # 3:0.4
Enter the Void Volume Ratio for Material # 3:0
Enter the Use and Cure Temperatures for Material # 3:70 70
Enter the Percentage of Moisture Content by Weight for
Material # 3: 0.0

Note: the Blade  Cross Section is made of
----  Symmetric Composite and Material Layers
      are Numbered from Outside to Inside

   For Composite Blade ---
       Enter Thickness of Material # 1 :0.005
       Enter Thickness of Material # 2 :0.02
       Enter Thickness of Material # 3 :0.005

       Enter First Ply Orientation in Material # 1 :0
       Enter First Ply Orientation in Material # 2 :45
       Enter First Ply Orientation in Material # 3 :0

       Enter Ply Thickness in Material # 1 :0.005
       Enter Ply Thickness in Material # 2 :0.02
       Enter Ply Thickness in Material # 3 :0.005

 The Blade Offsets are defined as..
   x = ACLX*Z + BCLX*Z**2 + CCLX*Z**3
   y = ACLY*Z + BCLY*Z**2 + CCLY*Z**3
 where Z is spanwise variable
       y is chordwise variable
  and  x is transverse variable

 The Offsets are Defaulted to Zero, to Accept the
 Default Values Hit Return or Enter Now ACLX, BCLX,
 CCLX, ACLY, BCLY, and CCLY:
```

Pressure Data

This is the Third Section of the Input File Where Pressure Loading Data are Defined. If Pressure Loading is Applied, the User Has the Option of Either Providing Data Thru a File or Entering a Uniform

```
Pressure in This Section. Refer to the User's Manual for Details.

Is there Any Pressure Loading (Enter Yes or No):y

Will the Pressure Data Be Supplied Thru a Data File
            (Enter Yes or No) :n

The Pressure Entered Here is Uniform For All Elements
Enter the Value of the Element Pressure:3

Fatigue Life Data
-----------------

This Section of  the Input File is for Fatigue Data.   If Fatigue
Analysis is Desired, then Data  Such as Static and Dynamic  Stress
Limits are Entered Here.  Refer to the User's Manual for Details.

Do You Need to Enter Fatigue life Data for Forcing
Function Calculation? (Enter Yes or No):y
Enter Static and Dynamic Stress Limits (psi):75000 30000
Enter Multiple of Static Pressure:0
Enter Root Current, Reference, and Melting  Temperatures (F):70 70 2000
Enter the Exponent:1
Enter the Forcing Function:1

Boundary Conditions Data
------------------------

Boundary  Conditions  Data Are  Defaulted,  i.e.,  All  Degrees of
Freedom at the Blade Root are Restrained.  To Change the Defaulted
Boundary Conditions, Refer to the User Manual, Section 2.0

The Input File Required to Run the BLASIM Code is  Generated
Under the Name BLASIM.INP. Use the Command or Job File Given
in the User's Manual to Run the Code on VAX or CRAY XMP.
```

B.3 Input File

The input file generated by PREBLASIM for this demonstration case is listed here:

```
SR2 Modified Composite Blade
NASTRAN GEOMETRY TYPE                                                       CARD A2
  4000.0                                3.0    400.0                        CARD A3
11                                                             2.0          CARD A4
GRID          1            2.0600  0.0000 -0.4710  0.7267                   CARD A6a
GRID          2            2.0600  0.0000 -0.1980  1.0125                   CARD A6a
GRID          3            2.0600  0.0000  0.0000  1.0857                   CARD A6a
GRID          4            2.0600  0.0000  0.1980  1.0125                   CARD A6a
GRID          5            2.0600  0.0000  0.4710  0.7267                   CARD A6a
GRID          6            2.7780  0.0650 -0.5500  0.6666                   CARD A6a
GRID          7            2.7780  0.0510 -0.2190  0.7926                   CARD A6a
GRID          8            2.7780  0.0240 -0.0200  0.8927                   CARD A6a
GRID          9            2.7780 -0.0030  0.1980  0.8587                   CARD A6a
GRID         10            2.7780  0.0000  0.4710  0.7465                   CARD A6a
GRID         11            3.6840  0.4940 -1.5130  0.0990                   CARD A6a
GRID         12            3.6840  0.2030 -0.6550  0.2737                   CARD A6a
GRID         13            3.6840 -0.0540  0.1990  0.3339                   CARD A6a
GRID         14            3.6840 -0.2780  1.0540  0.2339                   CARD A6a
GRID         15            3.6840 -0.4710  1.9120  0.0774                   CARD A6a
```

```
GRID        16           5.0360  0.6530 -1.5240  0.0688                  CARD A6a
GRID        17           5.0360  0.2770 -0.6760  0.1804                  CARD A6a
GRID        18           5.0360 -0.0700  0.1680  0.2059                  CARD A6a
GRID        19           5.0360 -0.3900  1.0150  0.1343                  CARD A6a
GRID        20           5.0360 -0.6840  1.8630  0.0356                  CARD A6a
GRID        21           6.3890  0.7950 -1.5640  0.0486                  CARD A6a
GRID        22           6.3890  0.3580 -0.7400  0.1198                  CARD A6a
GRID        23           6.3890 -0.0450  0.0810  0.1447                  CARD A6a
GRID        24           6.3890 -0.4260  0.9020  0.1122                  CARD A6a
GRID        25           6.3890 -0.7760  1.7250  0.0340                  CARD A6a
GRID        26           7.7420  0.8840 -1.4970  0.0362                  CARD A6a
GRID        27           7.7420  0.4030 -0.7110  0.0891                  CARD A6a
GRID        28           7.7420 -0.0490  0.0750  0.1064                  CARD A6a
GRID        29           7.7420 -0.4800  0.8600  0.0835                  CARD A6a
GRID        30           7.7420 -0.8830  1.6460  0.0260                  CARD A6a
GRID        31           9.0940  0.9510 -1.4200  0.0285                  CARD A6a
GRID        32           9.0940  0.4400 -0.6750  0.0702                  CARD A6a
GRID        33           9.0940 -0.0500  0.0680  0.0837                  CARD A6a
GRID        34           9.0940 -0.5250  0.8120  0.0651                  CARD A6a
GRID        35           9.0940 -0.9780  1.5560  0.0207                  CARD A6a
GRID        36          10.4470  0.9680 -1.2870  0.0233                  CARD A6a
GRID        37          10.4470  0.4570 -0.6140  0.0575                  CARD A6a
GRID        38          10.4470 -0.0450  0.0570  0.0684                  CARD A6a
GRID        39          10.4470 -0.5400  0.7290  0.0533                  CARD A6a
GRID        40          10.4470 -1.0260  1.4020  0.0173                  CARD A6a
GRID        41          11.3480  0.8950 -1.1220  0.0193                  CARD A6a
GRID        42          11.3480  0.4270 -0.5380  0.0484                  CARD A6a
GRID        43          11.3480 -0.0370  0.0450  0.0576                  CARD A6a
GRID        44          11.3480 -0.4980  0.6290  0.0449                  CARD A6a
GRID        45          11.3480 -0.9550  1.2130  0.0148                  CARD A6a
GRID        46          11.7990  0.8050 -0.9800  0.0137                  CARD A6a
GRID        47          11.7990  0.3860 -0.4710  0.0366                  CARD A6a
GRID        48          11.7990 -0.0310  0.0370  0.0435                  CARD A6a
GRID        49          11.7990 -0.4460  0.5450  0.0341                  CARD A6a
GRID        50          11.7990 -0.8600  1.0540  0.0107                  CARD A6a
GRID        51          12.2500  0.3810 -0.4520  0.0082                  CARD A6a
GRID        52          12.2500  0.1830 -0.2180  0.0283                  CARD A6a
GRID        53          12.2500 -0.0140  0.0170  0.0336                  CARD A6a
GRID        54          12.2500 -0.2110  0.2510  0.0265                  CARD A6a
GRID        55          12.2500 -0.4080  0.4850  0.0066                  CARD A6a
             0.0    1.086   0.000      0.0                               CARD A9
                                                 8.0                     CARD A10
   5    3    5    3    3    1    2    0    1  1.02307    1               CARD B1a
.0001.0001.000                                                           CARD B1b
 2  0.8927 5  0.1447 7  0.0837 9  0.057611  0.0336                       CARD B2
            32.00000              1                                      CARD B3
   1.10000  12.25000         2117.00000                                  CARD B4
  4200.000  3800.000   3    1    2    3                                  CARD B5
   0.70000   0.70000   0.70000 100.00000  0.000084   0.00001   0.00000   CARD B6b
   0.50000   0.90000   16   40          1                                CARD B7
MATCARD   TITFTIT6    0.40    0.00    70.00    70.00     0.00            CARD B8b
MATCARD   T300EPOC    0.40    0.00    70.00    70.00     0.00            CARD B8b
MATCARD   TITFTIT6    0.40    0.00    70.00    70.00     0.00            CARD B8b
  0.0050  0.0200  0.0050                                                 CARD B9b
  0.0000 45.0000  0.0000                                                 CARD B9c
  0.0050  0.0200  0.0050                                                 CARD B9d
  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000                         CARD B9e
ELEMENT PRESSURE DATA
PRESSURE            3.00                                                 CARD D2
PRESSURE            3.00                                                 CARD D2
PRESSURE            3.00                                                 CARD D2
PRESSURE            3.00                                                 CARD D2
PRESSURE            3.00                                                 CARD D2
PRESSURE            3.00                                                 CARD D2
```

```
PRESSURE          3.00                                          CARD  D2
PRESSURE          3.00                                          CARD  D2
PRESSURE          3.00                                          CARD  D2
PRESSURE          3.00                                          CARD  D2
PRESSURE          3.00                                          CARD  D2
PRESSURE          3.00                                          CARD  D2
PRESSURE          3.00                                          CARD  D2
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PRESSURE            3.00                                           CARD D2
FATIGUE LIFE DATA
STATIC LIMIT     75000.0                                           CARD E2
DYNAMIC LIMIT    30000.0                                           CARD E3
MULTIPLE             0.0                                           CARD E4
TMELT             2000.0                                           CARD E5
TREF                70.0                                           CARD E6
TCURRENT            70.0                                           CARD E7
EXPONENT             1.0                                           CARD E8
FORCING FUNCTION     1.0                                           CARD E9
```

The output file obtained by running BLASIM using this input file will be very similar to the one shown in Section A.3, hence it is not shown here.

B.4 ICAN Data Bank

The ICAN Data Bank is divided into two parts: fiber material properties and matrix material properties. The Data Bank that is currently available with the BLASIM code is listed below:

```
FIBER PROPERTIES
ADHX  FIBER EQUIVALENT PROPERTIES OF ADHESIVE.
Number of fibers per end       Nf            1        number
Filament equivalent diameter   df        0.500E-03    inches
Weight density                 Rhof      0.400E-01    lb/in**3
Normal moduli (11)             Ef11      0.300E+06    psi
Normal moduli (22)             Ef22      0.300E+06    psi
Poisson"s ratio (12)           Nuf12     0.450E+00    non-dim
Poisson"s ratio (23)           Nuf23     0.450E+00    non-dim
Shear moduli (12)              Gf12      0.103E+06    psi
Shear moduli (23)              Gf23      0.103E+06    psi
Thermal expansion coef. (11)   Alfaf11   0.570E-04    in/in/F
Thermal expansion coef. (22)   Alfaf22   0.570E-04    in/in/F
Heat conductivity (11)         Kf11      0.125E+01    BTU-in/hr/in**2/F
Heat conductivity (22)         Kf22      0.125E+01    BTU-in/hr/in**2/F
Heat capacity                  Cf        0.250E+00    BTU/lb/F
Fiber tensile strength         SfT       0.800E+04    psi
Fiber compressive strength     SfC       0.150E+05    psi

ADHF  FIBER EQUIVALENT  PROPERTIES OF ADHESIVE.
Number of fibers per end       Nf            1        number
Filament equivalent diameter   df        0.500E-03    inches
Weight density                 Rhof      0.400E-01    lb/in**3
Normal moduli (11)             Ef11      0.300E+06    psi
Normal moduli (22)             Ef22      0.300E+06    psi
Poisson"s ratio (12)           Nuf12     0.450E+00    non-dim
Poisson"s ratio (23)           Nuf23     0.450E+00    non-dim
Shear moduli (12)              Gf12      0.103E+06    psi
Shear moduli (23)              Gf23      0.103E+06    psi
Thermal expansion coef. (11)   Alfaf11   0.360E-04    in/in/F
Thermal expansion coef. (22)   Alfaf22   0.360E-04    in/in/F
Heat conductivity (11)         Kf11      0.125E+01    BTU-in/hr/in**2/F
```

Heat conductivity (22)	Kf22	0.125E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.250E+00	BTU/lb/F
Fiber tensile strength	SfT	0.710E+04	psi
Fiber compressive strength	SfC	0.140E+05	psi

HALF

Number of fibers per end	Nf	10000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.815E-03	lb/in**3
Normal moduli (11)	Ef11	0.890E+05	psi
Normal moduli (22)	Ef22	0.371E+05	psi
Poisson"s ratio (12)	Nuf12	0.300E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.300E+00	non-dim
Shear moduli (12)	Gf12	0.114E+05	psi
Shear moduli (23)	Gf23	0.171E+05	psi
Thermal expansion coef. (11)	Alfaf11	0.126E-04	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.126E-04	in/in/F
Heat conductivity (11)	Kf11	0.518E-01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.259E-01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.220E+00	BTU/lb/F
Fiber tensile strength	SfT	0.400E+06	psi
Fiber compressive strength	SfC	0.400E+06	psi

F185 ISOTROPIC SOLID . MARCH 4, 1990.

Number of fibers per end	Nf	3000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.443E-01	lb/in**3
Normal moduli (11)	Ef11	0.491E+08	psi
Normal moduli (22)	Ef22	0.491E+08	psi
Poisson"s ratio (12)	Nuf12	0.300E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.300E+00	non-dim
Shear moduli (12)	Gf12	0.189E+08	psi
Shear moduli (23)	Gf23	0.189E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.219E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.219E-05	in/in/F
Heat conductivity (11)	Kf11	0.250E+00	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.250E+00	BTU-in/hr/in**2/F
Heat capacity	Cf	0.125E+01	BTU/lb/F
Fiber tensile strength	SfT	0.650E+04	psi
Fiber compressive strength	SfC	0.210E+05	psi

F186 ISOTROPIC SOLID . MARCH 4, 1990.

Number of fibers per end	Nf	3000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.443E-01	lb/in**3
Normal moduli (11)	Ef11	0.243E+08	psi
Normal moduli (22)	Ef22	0.243E+08	psi
Poisson"s ratio (12)	Nuf12	0.300E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.300E+00	non-dim
Shear moduli (12)	Gf12	0.935E+07	psi
Shear moduli (23)	Gf23	0.935E+07	psi
Thermal expansion coef. (11)	Alfaf11	0.345E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.345E-05	in/in/F
Heat conductivity (11)	Kf11	0.250E+00	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.250E+00	BTU-in/hr/in**2/F
Heat capacity	Cf	0.125E+01	BTU/lb/F
Fiber tensile strength	SfT	0.650E+04	psi
Fiber compressive strength	SfC	0.210E+05	psi

T300 GRAPHITE FIBER.

Number of fibers per end	Nf	3000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.640E-01	lb/in**3
Normal moduli (11)	Ef11	0.320E+08	psi

```
Normal moduli (22)             Ef22       0.200E+07    psi
Poisson"s ratio (12)           Nuf12      0.200E+00    non-dim
Poisson"s ratio (23)           Nuf23      0.250E+00    non-dim
Shear moduli (12)              Gf12       0.130E+07    psi
Shear moduli (23)              Gf23       0.700E+06    psi
Thermal expansion coef. (11)   Alfaf11    -.550E-06    in/in/F
Thermal expansion coef. (22)   Alfaf22    0.560E-05    in/in/F
HEAT CONDUCTIVITY (11)         KF11       0.403E+03    BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)         KF22       0.403E+02    BTU-IN/HR/IN**2/F
Heat capacity                  Cf         0.170E+00    BTU/lb/F
Fiber tensile strength         SfT        0.350E+06    psi
Fiber compressive strength     SfC        0.300E+06    psi

DALF  TO CHECK DALE BROWN'S DATA
Number of fibers per end       Nf          3000        number
Filament equivalent diameter   df         0.226E-03    inches
Weight density                 Rhof       0.533E-01    lb/in**3
Normal moduli (11)             Ef11       0.807E+08    psi
Normal moduli (22)             Ef22       0.229E+08    psi
Poisson"s ratio (12)           Nuf12      0.197E+00    non-dim
Poisson"s ratio (23)           Nuf23      0.325E+00    non-dim
Shear moduli (12)              Gf12       0.420E+07    psi
Shear moduli (23)              Gf23       0.769E+06    psi
Thermal expansion coef. (11)   Alfaf11    0.238E-04    in/in/F
Thermal expansion coef. (22)   Alfaf22    0.183E-04    in/in/F
Heat conductivity (11)         Kf11       0.250E+03    BTU-in/hr/in**2/F
Heat conductivity (22)         Kf22       0.546E+03    BTU-in/hr/in**2/F
Heat capacity                  Cf         0.145E+01    BTU/lb/F
Fiber tensile strength         SfT        0.539E+06    psi
Fiber compressive strength     SfC        0.256E+06    psi

MOD2  GRAPHITE FIBER - INTERMEDIATE MODULUS.
Number of fibers per end       Nf         10000        number
Filament equivalent diameter   df         0.300E-03    inches
Weight density                 Rhof       0.630E-01    lb/in**3
Normal moduli (11)             Ef11       0.380E+08    psi
Normal moduli (22)             Ef22       0.110E+07    psi
Poisson"s ratio (12)           Nuf12      0.200E+00    non-dim
Poisson"s ratio (23)           Nuf23      0.250E+00    non-dim
Shear moduli (12)              Gf12       0.150E+07    psi
Shear moduli (23)              Gf23       0.800E+06    psi
Thermal expansion coef. (11)   Alfaf11    -.550E-06    in/in/F
Thermal expansion coef. (22)   Alfaf22    0.560E-05    in/in/F
HEAT CONDUCTIVITY (11)         KF11       0.403E+01    BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)         KF22       0.403E+00    BTU-IN/HR/IN**2/F
Heat capacity                  Cf         0.170E+00    BTU/lb/F
Fiber tensile strength         SfT        0.350E+06    psi
Fiber compressive strength     SfC        0.250E+06    psi

MOD1  GRAPHITE FIBER - HIGH MODULUS.
Number of fibers per end       Nf         10000        number
Filament equivalent diameter   df         0.300E-03    inches
Weight density                 Rhof       0.720E-01    lb/in**3
Normal moduli (11)             Ef11       0.600E+08    psi
Normal moduli (22)             Ef22       0.900E+06    psi
Poisson"s ratio (12)           Nuf12      0.200E+00    non-dim
Poisson"s ratio (23)           Nuf23      0.250E+00    non-dim
Shear moduli (12)              Gf12       0.110E+07    psi
Shear moduli (23)              Gf23       0.700E+06    psi
Thermal expansion coef. (11)   Alfaf11    -.550E-06    in/in/F
Thermal expansion coef. (22)   Alfaf22    0.560E-05    in/in/F
HEAT CONDUCTIVITY (11)         KF11       0.403E+01    BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)         KF22       0.403E+00    BTU-IN/HR/IN**2/F
Heat capacity                  Cf         0.170E+00    BTU/lb/F
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Fiber tensile strength	SfT	0.250E+06	psi
Fiber compressive strength	SfC	0.200E+06	psi

HMSF HIGH MODULUS SURFACE TREATED FIBER.

Number of fibers per end	Nf	10000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.703E-01	lb/in**3
Normal moduli (11)	Ef11	0.550E+08	psi
Normal moduli (22)	Ef22	0.900E+06	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.250E+00	non-dim
Shear moduli (12)	Gf12	0.110E+07	psi
Shear moduli (23)	Gf23	0.700E+06	psi
Thermal expansion coef. (11)	Alfaf11	-.550E-06	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.560E-05	in/in/F
HEAT CONDUCTIVITY (11)	KF11	0.403E+01	BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)	KF22	0.403E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.280E+06	psi
Fiber compressive strength	SfC	0.200E+06	psi

HT-S

Number of fibers per end	Nf	10000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.640E-01	lb/in**3
Normal moduli (11)	Ef11	0.320E+08	psi
Normal moduli (22)	Ef22	0.250E+07	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.250E+00	non-dim
Shear moduli (12)	Gf12	0.150E+07	psi
Shear moduli (23)	Gf23	0.100E+07	psi
Thermal expansion coef. (11)	Alfaf11	-.550E-06	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.560E-05	in/in/F
HEAT CONDUCTIVITY (11)	KF11	0.403E+01	BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)	KF22	0.403E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.350E+06	psi
Fiber compressive strength	SfC	0.300E+06	psi

AS-- GRAPHITE FIBER.

Number of fibers per end	Nf	10000	number
Filament equivalent diameter	df	0.300E-03	inches
Weight density	Rhof	0.630E-01	lb/in**3
Normal moduli (11)	Ef11	0.310E+08	psi
Normal moduli (22)	Ef22	0.200E+07	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.250E+00	non-dim
Shear moduli (12)	Gf12	0.200E+07	psi
Shear moduli (23)	Gf23	0.100E+07	psi
Thermal expansion coef. (11)	Alfaf11	-.550E-06	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.560E-05	in/in/F
HEAT CONDUCTIVITY (11)	KF11	0.403E+01	BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)	KF22	0.403E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.400E+06	psi
Fiber compressive strength	SfC	0.400E+06	psi

BOR4 BORON FIBER - 4 MIL DIAMETER.

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.400E-02	inches
Weight density	Rhof	0.950E-01	lb/in**3
Normal moduli (11)	Ef11	0.580E+08	psi
Normal moduli (22)	Ef22	0.580E+08	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim

Poisson"s ratio (23)	Nuf23	0.200E+00	non-dim
Shear moduli (12)	Gf12	0.242E+08	psi
Shear moduli (23)	Gf23	0.242E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.280E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.280E-05	in/in/F
Heat conductivity (11)	Kf11	0.155E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.155E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.310E+00	BTU/lb/F
Fiber tensile strength	SfT	0.600E+06	psi
Fiber compressive strength	SfC	0.700E+06	psi

SGLA S- GLASS FIBER.

Number of fibers per end	Nf	204	number
Filament equivalent diameter	df	0.360E-03	inches
Weight density	Rhof	0.900E-01	lb/in**3
Normal moduli (11)	Ef11	0.124E+08	psi
Normal moduli (22)	Ef22	0.124E+08	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.200E+00	non-dim
Shear moduli (12)	Gf12	0.517E+07	psi
Shear moduli (23)	Gf23	0.517E+07	psi
Thermal expansion coef. (11)	Alfaf11	0.280E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.280E-05	in/in/F
HEAT CONDUCTIVITY (11)	KF11	0.625E+00	BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)	KF22	0.625E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.360E+06	psi
Fiber compressive strength	SfC	0.300E+06	psi

KEVL KEVLAR FIBER.

Number of fibers per end	Nf	580	number
Filament equivalent diameter	df	0.460E-03	inches
Weight density	Rhof	0.530E-01	lb/in**3
Normal moduli (11)	Ef11	0.220E+08	psi
Normal moduli (22)	Ef22	0.600E+06	psi
Poisson"s ratio (12)	Nuf12	0.350E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.350E+00	non-dim
Shear moduli (12)	Gf12	0.420E+06	psi
Shear moduli (23)	Gf23	0.220E+06	psi
Thermal expansion coef. (11)	Alfaf11	-.220E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.300E-04	in/in/F
Heat conductivity (11)	Kf11	0.170E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.170E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.250E+00	BTU/lb/F
Fiber tensile strength	SfT	0.400E+06	psi
Fiber compressive strength	SfC	0.750E+05	psi

BOR5 BORON FIBER - 5 MIL DIAMETER.

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.560E-02	inches
Weight density	Rhof	0.950E-01	lb/in**3
Normal moduli (11)	Ef11	0.580E+08	psi
Normal moduli (22)	Ef22	0.580E+08	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.200E+00	non-dim
Shear moduli (12)	Gf12	0.242E+08	psi
Shear moduli (23)	Gf23	0.242E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.280E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.280E-05	in/in/F
Heat conductivity (11)	Kf11	0.155E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.155E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.310E+00	BTU/lb/F
Fiber tensile strength	SfT	0.600E+06	psi
Fiber compressive strength	SfC	0.700E+06	psi

BOR8 BORON FIBER - 8 MIL DIAMETER.

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.800E-02	inches
Weight density	Rhof	0.950E-01	lb/in**3
Normal moduli (11)	Ef11	0.580E+08	psi
Normal moduli (22)	Ef22	0.580E+08	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.200E+00	non-dim
Shear moduli (12)	Gf12	0.242E+08	psi
Shear moduli (23)	Gf23	0.242E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.280E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.280E-05	in/in/F
Heat conductivity (11)	Kf11	0.155E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.155E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.310E+00	BTU/lb/F
Fiber tensile strength	SfT	0.600E+06	psi
Fiber compressive strength	SfC	0.700E+06	psi

EGLA E-GLASS FIBER.

Number of fibers per end	Nf	204	number
Filament equivalent diameter	df	0.360E-03	inches
Weight density	Rhof	0.900E-01	lb/in**3
Normal moduli (11)	Ef11	0.105E+08	psi
Normal moduli (22)	Ef22	0.105E+08	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.200E+00	non-dim
Shear moduli (12)	Gf12	0.437E+07	psi
Shear moduli (23)	Gf23	0.437E+07	psi
Thermal expansion coef. (11)	Alfaf11	0.280E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.280E-05	in/in/F
HEAT CONDUCTIVITY (11)	KF11	0.625E+00	BTU-IN/HR/IN**2/F
HEAT CONDUCTIVITY (22)	KF22	0.625E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.360E+06	psi
Fiber compressive strength	SfC	0.360E+06	psi

SW4M STAINLESS STEEL WIRE.

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.400E-02	inches
Weight density	Rhof	0.278E+00	lb/in**3
Normal moduli (11)	Ef11	0.290E+08	psi
Normal moduli (22)	Ef22	0.290E+08	psi
Poisson"s ratio (12)	Nuf12	0.300E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.300E+00	non-dim
Shear moduli (12)	Gf12	0.112E+08	psi
Shear moduli (23)	Gf23	0.112E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.560E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.560E-05	in/in/F
Heat conductivity (11)	Kf11	0.108E+03	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.108E+03	BTU-in/hr/in**2/F
Heat capacity	Cf	0.120E+00	BTU/lb/F
Fiber tensile strength	SfT	0.160E+06	psi
Fiber compressive strength	SfC	0.160E+06	psi

TITF TITANIUM FIBER.

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.430E-02	inches
Weight density	Rhof	0.161E+00	lb/in**3
Normal moduli (11)	Ef11	0.166E+08	psi
Normal moduli (22)	Ef22	0.166E+08	psi
Poisson"s ratio (12)	Nuf12	0.305E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.305E+00	non-dim
Shear moduli (12)	Gf12	0.636E+07	psi

Shear moduli (23)	Gf23	0.636E+07	psi
Thermal expansion coef. (11)	Alfaf11	0.571E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.571E-05	in/in/F
Heat conductivity (11)	Kf11	0.100E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.100E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.127E+00	BTU/lb/F
Fiber tensile strength	SfT	0.120E+06	psi
Fiber compressive strength	SfC	0.120E+06	psi

ADH1 ADHESIVE.

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.360E-03	inches
Weight density	Rhof	0.420E-01	lb/in**3
Normal moduli (11)	Ef11	0.211E+06	psi
Normal moduli (22)	Ef22	0.211E+06	psi
Poisson"s ratio (12)	Nuf12	0.410E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.410E+00	non-dim
Shear moduli (12)	Gf12	0.760E+06	psi
Shear moduli (23)	Gf23	0.760E+06	psi
Thermal expansion coef. (11)	Alfaf11	0.410E-04	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.410E-04	in/in/F
Heat conductivity (11)	Kf11	0.126E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.126E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.260E+00	BTU/lb/F
Fiber tensile strength	SfT	0.600E+04	psi
Fiber compressive strength	SfC	0.100E+05	psi

TUNG TUNGSTEN FIBER (W-1.5%THO2).

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.600E-02	inches
Weight density	Rhof	0.697E+00	lb/in**3
Normal moduli (11)	Ef11	0.521E+08	psi
Normal moduli (22)	Ef22	0.521E+08	psi
Poisson"s ratio (12)	Nuf12	0.290E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.290E+00	non-dim
Shear moduli (12)	Gf12	0.202E+08	psi
Shear moduli (23)	Gf23	0.202E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.244E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.244E-05	in/in/F
Heat conductivity (11)	Kf11	0.828E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.828E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.316E-01	BTU/lb/F
Fiber tensile strength	SfT	0.355E+06	psi
Fiber compressive strength	SfC	0.355E+06	psi

SICA SICA FIBER (W-1.5%THO2).

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.600E-02	inches
Weight density	Rhof	0.697E+00	lb/in**3
Normal moduli (11)	Ef11	0.580E+08	psi
Normal moduli (22)	Ef22	0.580E+08	psi
Poisson"s ratio (12)	Nuf12	0.250E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.250E+00	non-dim
Shear moduli (12)	Gf12	0.232E+08	psi
Shear moduli (23)	Gf23	0.232E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.270E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.270E-05	in/in/F
Heat conductivity (11)	Kf11	0.828E+01	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.828E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.316E-01	BTU/lb/F
Fiber tensile strength	SfT	0.355E+06	psi
Fiber compressive strength	SfC	0.355E+06	psi

P-75 HIGH MODULUS GRAPHITE FIBER

Number of fibers per end	Nf	10000	number
Filament equivalent diameter	df	0.390E-03	inches
Weight density	Rhof	0.720E-01	lb/in**3
Normal moduli (11)	Ef11	0.750E+08	psi
Normal moduli (22)	Ef22	0.900E+06	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.250E+00	non-dim
Shear moduli (12)	Gf12	0.110E+07	psi
Shear moduli (23)	Gf23	0.700E+06	psi
Thermal expansion coef. (11)	Alfaf11	-.700E-06	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.560E-05	in/in/F
Heat conductivity (11)	Kf11	0.900E+02	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.580E+02	BTU-in/hr/in**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.225E+06	psi
Fiber compressive strength	SfC	0.100E+06	psi

P100 HIGH MODULUS GRAPHITE FIBER

Number of fibers per end	Nf	10000	number
Filament equivalent diameter	df	0.390E-03	inches
Weight density	Rhof	0.780E-01	lb/in**3
Normal moduli (11)	Ef11	0.105E+09	psi
Normal moduli (22)	Ef22	0.900E+06	psi
Poisson"s ratio (12)	Nuf12	0.200E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.250E+00	non-dim
Shear moduli (12)	Gf12	0.110E+07	psi
Shear moduli (23)	Gf23	0.700E+06	psi
Thermal expansion coef. (11)	Alfaf11	-.900E-06	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.560E-05	in/in/F
Heat conductivity (11)	Kf11	0.250E+02	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.174E+01	BTU-in/hr/in**2/F
Heat capacity	Cf	0.170E+00	BTU/lb/F
Fiber tensile strength	SfT	0.325E+06	psi
Fiber compressive strength	SfC	0.200E+06	psi

SICA SILICON CARBIDE ON ALUMINUM. SEPT 7,1987. (6)

Number of fibers per end	Nf	1	number
Filament equivalent diameter	df	0.560E-02	inches
Weight density	Rhof	0.110E+00	lb/in**3
Normal moduli (11)	Ef11	0.620E+08	psi
Normal moduli (22)	Ef22	0.620E+08	psi
Poisson"s ratio (12)	Nuf12	0.300E+00	non-dim
Poisson"s ratio (23)	Nuf23	0.300E+00	non-dim
Shear moduli (12)	Gf12	0.238E+08	psi
Shear moduli (23)	Gf23	0.238E+08	psi
Thermal expansion coef. (11)	Alfaf11	0.180E-05	in/in/F
Thermal expansion coef. (22)	Alfaf22	0.180E-05	in/in/F
Heat conductivity (11)	Kf11	0.750E+00	BTU-in/hr/in**2/F
Heat conductivity (22)	Kf22	0.750E+00	BTU-in/hr/in**2/F
Heat capacity	Cf	0.290E+00	BTU/lb/F
Fiber tensile strength	SfT	0.500E+06	psi
Fiber compressive strength	SfC	0.650E+06	psi

OVER END OF FIBER PROPERTIES

MATRIX PROPERTIES
DALM DALE BROWN'S MATRIX OCT. 24, 1990.

Weight density	Rhom	0.475E-01	lb/in**3
Normal modulus	Em	0.449E+06	psi
Poisson"s ratio	Num	0.186E+00	non-dim
Thermal expansion coef.	Alfa m	0.292E-04	in/in/F
Matrix heat conductivity	Km	0.453E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.213E+00	BTU/lb/F
Matrix tensile strength	SmT	0.425E+05	psi

Matrix compressive strength	SmC	0.337E+05	psi
Matrix shear strength	SmS	0.271E+05	psi
Allowable tensile strain	eps mT	0.120E+00	in/in
Allowable compr. strain	eps mC	0.120E+00	in/in
Allowable shear strain	eps mS	0.120E+00	in/in
Allowable torsional strain	eps mTOR	0.120E+00	in/in
Void heat conductivity	kv	0.190E-01	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.364E+03	F

BORM BORON MATRIX. AUG 22 1990   (3)

Weight density	Rhom	0.950E-01	lb/in**3
Normal modulus	Em	0.580E+08	psi
Poisson"s ratio	Num	0.200E+00	non-dim
Thermal expansion coef.	Alfa m	0.280E-05	in/in/F
Matrix heat conductivity	Km	0.155E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.310E+00	BTU/lb/F
Matrix tensile strength	SmT	0.600E+06	psi
Matrix compressive strength	SmC	0.700E+06	psi
Matrix shear strength	SmS	0.100E+06	psi
Allowable tensile strain	eps mT	0.120E+00	in/in
Allowable compr. strain	eps mC	0.120E+00	in/in
Allowable shear strain	eps mS	0.120E+00	in/in
Allowable torsional strain	eps mTOR	0.120E+00	in/in
Void heat conductivity	kv	0.190E-01	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.180E+04	F

TI15 TITANIUM MATRIX. AUG 25, 1988.   (3)

Weight density	Rhom	0.172E+00	lb/in**3
Normal modulus	Em	0.123E+08	psi
Poisson"s ratio	Num	0.320E+00	non-dim
Thermal expansion coef.	Alfa m	0.450E-05	in/in/F
Matrix heat conductivity	Km	0.390E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.120E+00	BTU/lb/F
Matrix tensile strength	SmT	0.130E+06	psi
Matrix compressive strength	SmC	0.130E+06	psi
Matrix shear strength	SmS	0.910E+05	psi
Allowable tensile strain	eps mT	0.120E+00	in/in
Allowable compr. strain	eps mC	0.120E+00	in/in
Allowable shear strain	eps mS	0.120E+00	in/in
Allowable torsional strain	eps mTOR	0.120E+00	in/in
Void heat conductivity	kv	0.190E-01	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.180E+04	F

ADHM EQUVIVALENT MATRIX PROPS. FOR ADHESIVE.

Weight density	Rhom	0.400E-01	lb/in**3
Normal modulus	Em	0.300E+06	psi
Poisson"s ratio	Num	0.450E+00	non-dim
Thermal expansion coef.	Alfa m	0.360E-04	in/in/F
Matrix heat conductivity	Km	0.125E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.710E+04	psi
Matrix compressive strength	SmC	0.140E+05	psi
Matrix shear strength	SmS	0.710E+04	psi
Allowable tensile strain	eps mT	0.810E-01	in/in
Allowable compr. strain	eps mC	0.150E+00	in/in
Allowable shear strain	eps mS	0.100E+00	in/in
Allowable torsional strain	eps mTOR	0.100E+00	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.250E+03	F

ADHX EQUVIVALENT MATRIX PROPS. FOR ADHESIVE.

Weight density	Rhom	0.400E-01	lb/in**3
Normal modulus	Em	0.300E+06	psi
Poisson"s ratio	Num	0.450E+00	non-dim

Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
Matrix heat conductivity	Km	0.125E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.800E+04	psi
Matrix compressive strength	SmC	0.150E+05	psi
Matrix shear strength	SmS	0.800E+04	psi
Allowable tensile strain	eps mT	0.810E-01	in/in
Allowable compr. strain	eps mC	0.150E+00	in/in
Allowable shear strain	eps mS	0.100E+00	in/in
Allowable torsional strain	eps mTOR	0.100E+00	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.350E+03	F
HALM			
Weight density	Rhom	0.815E-03	lb/in**3
Normal modulus	Em	0.890E+05	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.126E-04	in/in/F
Matrix heat conductivity	Km	0.259E-01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.220E+00	BTU/lb/F
Matrix tensile strength	SmT	0.800E+04	psi
Matrix compressive strength	SmC	0.150E+05	psi
Matrix shear strength	SmS	0.800E+04	psi
Allowable tensile strain	eps mT	0.810E-01	in/in
Allowable compr. strain	eps mC	0.150E+00	in/in
Allowable shear strain	eps mS	0.100E+00	in/in
Allowable torsional strain	eps mTOR	0.100E+00	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.120E+04	F
ALT6 ALUMINUM MATRIX. DEC 16,	1987.	(1)	
Weight density	Rhom	0.980E-01	lb/in**3
Normal modulus	Em	0.100E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.131E-04	in/in/F
Matrix heat conductivity	Km	0.866E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.230E+00	BTU/lb/F
Matrix tensile strength	SmT	0.180E+05	psi
Matrix compressive strength	SmC	0.180E+05	psi
Matrix shear strength	SmS	0.120E+05	psi
Allowable tensile strain	eps mT	0.300E+00	in/in
Allowable compr. strain	eps mC	0.300E+00	in/in
Allowable shear strain	eps mS	0.300E+00	in/in
Allowable torsional strain	eps mTOR	0.300E+00	in/in
Void heat conductivity	kv	0.190E-01	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.108E+04	F
R934 SIMULATION OF 934 RESIN			
Weight density	Rhom	0.470E-01	lb/in**3
Normal modulus	Em	0.560E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.360E-04	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.710E+04	psi
Matrix compressive strength	SmC	0.350E+05	psi
Matrix shear strength	SmS	0.500E+04	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.350E-01	in/in
Allowable torsional strain	eps mTOR	0.350E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.392E+03	F

XXXX F185 NEAT RESIN CASTING. SEPT. 7, 1984.

Weight density	Rhom	0.443E-01	lb/in**3
Normal modulus	Em	0.400E+06	psi
Poisson"s ratio	Num	0.450E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.650E+04	psi
Matrix compressive strength	SmC	0.210E+05	psi
Matrix shear strength	SmS	0.650E+04	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in
Allowable torsional strain	eps mTOR	0.380E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

F185 NEAT RESIN CASTING. SEPT. 7, 1984.

Weight density	Rhom	0.443E-01	lb/in**3
Normal modulus	Em	0.491E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.219E-05	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.650E+04	psi
Matrix compressive strength	SmC	0.210E+05	psi
Matrix shear strength	SmS	0.650E+04	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in
Allowable torsional strain	eps mTOR	0.380E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

F186 NEAT RESIN CASTING. SEPT. 7, 1984.

Weight density	Rhom	0.443E-01	lb/in**3
Normal modulus	Em	0.243E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.345E-05	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.650E+04	psi
Matrix compressive strength	SmC	0.210E+05	psi
Matrix shear strength	SmS	0.650E+04	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in
Allowable torsional strain	eps mTOR	0.380E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

SPOX IMHS INTERMEDIATE MODULUS HIGH STRENGTH MATRIX.

Weight density	Rhom	0.443E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.410E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.150E+05	psi
Matrix compressive strength	SmC	0.300E+05	psi
Matrix shear strength	SmS	0.150E+05	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in

Allowable torsional strain	eps mTOR	0.380E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

GK60 IMLS INTERMEDIATE MODULUS LOW STRENGTH MATRIX.

Weight density	Rhom	0.460E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.410E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.700E+04	psi
Matrix compressive strength	SmC	0.210E+05	psi
Matrix shear strength	SmS	0.700E+04	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in
Allowable torsional strain	eps mTOR	0.380E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

EPOX IMHS INTERMEDIATE MODULUS HIGH STRENGTH MATRIX.

Weight density	Rhom	0.443E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.428E-04	in/in/F
MATRIX HEAT CONDUCTIVITY	KM	0.104E+00	BTU-IN/HR/IN**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.150E+05	psi
Matrix compressive strength	SmC	0.350E+05	psi
Matrix shear strength	SmS	0.130E+05	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.450E-01	in/in
Allowable torsional strain	eps mTOR	0.450E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

ERLA HMHS HIGH MODULUS HIGH STRENGTH MATRIX.

Weight density	Rhom	0.450E-01	lb/in**3
Normal modulus	Em	0.750E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.400E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.200E+05	psi
Matrix compressive strength	SmC	0.500E+05	psi
Matrix shear strength	SmS	0.150E+05	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.400E-01	in/in
Allowable torsional strain	eps mTOR	0.400E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

POLY POLYIMIDE MATRIX.

Weight density	Rhom	0.440E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.200E-04	in/in/F
Matrix heat conductivity	Km	0.146E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.150E+05	psi
Matrix compressive strength	SmC	0.300E+05	psi

Matrix shear strength	SmS	0.130E+05	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.400E-01	in/in
Allowable shear strain	eps mS	0.350E-01	in/in
Allowable torsional strain	eps mTOR	0.350E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.700E+03	F

ALTX ALUMINUM MATRIX.

Weight density	Rhom	0.950E-01	lb/in**3
Normal modulus	Em	0.100E+08	psi
Poisson"s ratio	Num	0.330E+00	non-dim
Thermal expansion coef.	Alfa m	0.129E-04	in/in/F
Matrix heat conductivity	Km	0.866E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.230E+00	BTU/lb/F
Matrix tensile strength	SmT	0.520E+05	psi
Matrix compressive strength	SmC	0.520E+05	psi
Matrix shear strength	SmS	0.260E+05	psi
Allowable tensile strain	eps mT	0.520E-02	in/in
Allowable compr. strain	eps mC	0.520E-02	in/in
Allowable shear strain	eps mS	0.905E-02	in/in
Allowable torsional strain	eps mTOR	0.905E-02	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.108E+04	F

TIT6 TITANIUM MATRIX.

Weight density	Rhom	0.161E+00	lb/in**3
Normal modulus	Em	0.165E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-05	in/in/F
Matrix heat conductivity	Km	0.100E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.127E+00	BTU/lb/F
Matrix tensile strength	SmT	0.120E+06	psi
Matrix compressive strength	SmC	0.120E+06	psi
Matrix shear strength	SmS	0.800E+05	psi
Allowable tensile strain	eps mT	0.730E-02	in/in
Allowable compr. strain	eps mC	0.730E-02	in/in
Allowable shear strain	eps mS	0.124E-01	in/in
Allowable torsional strain	eps mTOR	0.124E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.150E+04	F

TIXX TITANIUM MATRIX.

Weight density	Rhom	0.161E+00	lb/in**3
Normal modulus	Em	0.130E+08	psi
Poisson"s ratio	Num	0.360E+00	non-dim
Thermal expansion coef.	Alfa m	0.540E-05	in/in/F
Matrix heat conductivity	Km	0.100E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.127E+00	BTU/lb/F
Matrix tensile strength	SmT	0.120E+06	psi
Matrix compressive strength	SmC	0.120E+06	psi
Matrix shear strength	SmS	0.800E+05	psi
Allowable tensile strain	eps mT	0.730E-02	in/in
Allowable compr. strain	eps mC	0.730E-02	in/in
Allowable shear strain	eps mS	0.124E-01	in/in
Allowable torsional strain	eps mTOR	0.124E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.185E+04	F

EPOC EPOXY MATRIX.

Weight density	Rhom	0.440E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.360E-04	in/in/F

Matrix heat conductivity	Km	0.146E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.150E+05	psi
Matrix compressive strength	SmC	0.250E+05	psi
Matrix shear strength	SmS	0.130E+05	psi
Allowable tensile strain	eps mT	0.200E-02	in/in
Allowable compr. strain	eps mC	0.500E-02	in/in
Allowable shear strain	eps mS	0.350E-02	in/in
Allowable torsional strain	eps mTOR	0.350E-02	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.410E+03	F

SSAL STAINLESS STEEL MATRIX.

Weight density	Rhom	0.281E+00	lb/in**3
Normal modulus	Em	0.289E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-05	in/in/F
Matrix heat conductivity	Km	0.158E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.120E+00	BTU/lb/F
Matrix tensile strength	SmT	0.160E+06	psi
Matrix compressive strength	SmC	0.160E+06	psi
Matrix shear strength	SmS	0.120E+06	psi
Allowable tensile strain	eps mT	0.550E-02	in/in
Allowable compr. strain	eps mC	0.550E-02	in/in
Allowable shear strain	eps mS	0.104E-01	in/in
Allowable torsional strain	eps mTOR	0.104E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.266E+04	F

GV60

Weight density	Rhom	0.460E-01	lb/in**3
Normal modulus	Em	0.100E+04	psi
Poisson"s ratio	Num	0.410E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.700E+04	psi
Matrix compressive strength	SmC	0.210E+05	psi
Matrix shear strength	SmS	0.700E+04	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in
Allowable torsional strain	eps mTOR	0.380E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.410E+03	F

PMRP PMR POLYIMIDE MATRIX.

Weight density	Rhom	0.440E-01	lb/in**3
Normal modulus	Em	0.470E+06	psi
Poisson"s ratio	Num	0.360E+00	non-dim
Thermal expansion coef.	Alfa m	0.280E-04	in/in/F
Matrix heat conductivity	Km	0.146E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.810E+04	psi
Matrix compressive strength	SmC	0.165E+05	psi
Matrix shear strength	SmS	0.810E+04	psi
Allowable tensile strain	eps mT	0.183E-01	in/in
Allowable compr. strain	eps mC	0.350E-01	in/in
Allowable shear strain	eps mS	0.500E-01	in/in
Allowable torsional strain	eps mTOR	0.500E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.700E+03	F

PM15 PMR POLYIMIDE MATRIX.

Weight density	Rhom	0.440E-01	lb/in**3
Normal modulus	Em	0.470E+06	psi
Poisson"s ratio	Num	0.360E+00	non-dim
Thermal expansion coef.	Alfa m	0.280E-04	in/in/F
Matrix heat conductivity	Km	0.146E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.810E+04	psi
Matrix compressive strength	SmC	0.165E+05	psi
Matrix shear strength	SmS	0.810E+04	psi
Allowable tensile strain	eps mT	0.183E-01	in/in
Allowable compr. strain	eps mC	0.350E-01	in/in
Allowable shear strain	eps mS	0.500E-01	in/in
Allowable torsional strain	eps mTOR	0.500E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.600E+03	F

BERY BERYLLIUM MATRIX.

Weight density	Rhom	0.570E-01	lb/in**3
Normal modulus	Em	0.440E+08	psi
Poisson"s ratio	Num	0.100E+00	non-dim
Thermal expansion coef.	Alfa m	0.640E-05	in/in/F
Matrix heat conductivity	Km	0.968E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.450E+00	BTU/lb/F
Matrix tensile strength	SmT	0.133E+06	psi
Matrix compressive strength	SmC	0.133E+06	psi
Matrix shear strength	SmS	0.770E+05	psi
Allowable tensile strain	eps mT	0.302E-02	in/in
Allowable compr. strain	eps mC	0.302E-02	in/in
Allowable shear strain	eps mS	0.385E-02	in/in
Allowable torsional strain	eps mTOR	0.385E-02	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.234E+04	F

NM40

Weight density	Rhom	0.320E+00	lb/in**3
Normal modulus	Em	0.260E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.770E-05	in/in/F
Matrix heat conductivity	Km	0.126E+02	BTU-in/hr/in**2/F
Heat capacity	Cm	0.102E+00	BTU/lb/F
Matrix tensile strength	SmT	0.250E+05	psi
Matrix compressive strength	SmC	0.250E+05	psi
Matrix shear strength	SmS	0.144E+05	psi
Allowable tensile strain	eps mT	0.960E-03	in/in
Allowable compr. strain	eps mC	0.960E-03	in/in
Allowable shear strain	eps mS	0.144E-02	in/in
Allowable torsional strain	eps mTOR	0.144E-02	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.410E+03	F

FMTH FM1000 ADHESIVE MATRIX.

Weight density	Rhom	0.420E-01	lb/in**3
Normal modulus	Em	0.210E+06	psi
Poisson"s ratio	Num	0.400E+00	non-dim
Thermal expansion coef.	Alfa m	0.400E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.260E+00	BTU/lb/F
Matrix tensile strength	SmT	0.600E+04	psi
Matrix compressive strength	SmC	0.100E+05	psi
Matrix shear strength	SmS	0.600E+04	psi
Allowable tensile strain	eps mT	0.286E-01	in/in
Allowable compr. strain	eps mC	0.476E+00	in/in
Allowable shear strain	eps mS	0.800E-01	in/in
Allowable torsional strain	eps mTOR	0.800E-01	in/in

Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.410E+03	F

LMLS LOW MODULUS LOW STRENGTH MATRIX.

Weight density	Rhom	0.420E-01	lb/in**3
Normal modulus	Em	0.320E+06	psi
Poisson"s ratio	Num	0.430E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.800E+04	psi
Matrix compressive strength	SmC	0.150E+05	psi
Matrix shear strength	SmS	0.800E+04	psi
Allowable tensile strain	eps mT	0.810E-01	in/in
Allowable compr. strain	eps mC	0.150E+00	in/in
Allowable shear strain	eps mS	0.100E+00	in/in
Allowable torsional strain	eps mTOR	0.100E+00	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.350E+03	F

IMLS INTERMEDIATE MODULUS LOW STRENGTH MATRIX.

Weight density	Rhom	0.460E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.410E+00	non-dim
Thermal expansion coef.	Alfa m	0.570E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.700E+04	psi
Matrix compressive strength	SmC	0.210E+05	psi
Matrix shear strength	SmS	0.700E+04	psi
Allowable tensile strain	eps mT	0.140E-01	in/in
Allowable compr. strain	eps mC	0.420E-01	in/in
Allowable shear strain	eps mS	0.320E-01	in/in
Allowable torsional strain	eps mTOR	0.320E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

IMHS INTERMEDIATE MODULUS HIGH STRENGTH MATRIX.

Weight density	Rhom	0.440E-01	lb/in**3
Normal modulus	Em	0.500E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.360E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.150E+05	psi
Matrix compressive strength	SmC	0.350E+05	psi
Matrix shear strength	SmS	0.130E+05	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.350E-01	in/in
Allowable torsional strain	eps mTOR	0.350E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

HMHS HIGH MODULUS HIGH STRENGTH MATRIX.

Weight density	Rhom	0.450E-01	lb/in**3
Normal modulus	Em	0.750E+06	psi
Poisson"s ratio	Num	0.350E+00	non-dim
Thermal expansion coef.	Alfa m	0.400E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.200E+05	psi
Matrix compressive strength	SmC	0.500E+05	psi
Matrix shear strength	SmS	0.150E+05	psi

Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.400E-01	in/in
Allowable torsional strain	eps mTOR	0.400E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.420E+03	F

MAGN MAGNESIUM -- METAL MATRIX.AZ31B-H24

Weight density	Rhom	0.600E-01	lb/in**3
Normal modulus	Em	0.600E+07	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.140E-04	in/in/F
Matrix heat conductivity	Km	0.667E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.240E+00	BTU/lb/F
Matrix tensile strength	SmT	0.400E+05	psi
Matrix compressive strength	SmC	0.400E+05	psi
Matrix shear strength	SmS	0.250E+05	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.400E-01	in/in
Allowable torsional strain	eps mTOR	0.400E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.105E+04	F

FECR SUPERALLOY (FE-25%CR-4%AL-1%Y) MATRIX

Weight density	Rhom	0.260E+00	lb/in**3
Normal modulus	Em	0.302E+08	psi
Poisson"s ratio	Num	0.300E+00	non-dim
Thermal expansion coef.	Alfa m	0.528E-05	in/in/F
Matrix heat conductivity	Km	0.125E+01	BTU-in/hr/in**2/F
Heat capacity	Cm	0.112E+00	BTU/lb/F
Matrix tensile strength	SmT	0.110E+06	psi
Matrix compressive strength	SmC	0.110E+06	psi
Matrix shear strength	SmS	0.660E+05	psi
Allowable tensile strain	eps mT	0.256E-02	in/in
Allowable compr. strain	eps mC	0.256E-02	in/in
Allowable shear strain	eps mS	0.154E-02	in/in
Allowable torsional strain	eps mTOR	0.154E-02	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.105E+04	F

R930 SIMULATION OF 930 RESIN JULY 6,1990.

Weight density	Rhom	0.400E-01	lb/in**3
Normal modulus	Em	0.300E+06	psi
Poisson"s ratio	Num	0.450E+00	non-dim
Thermal expansion coef.	Alfa m	0.360E-04	in/in/F
Matrix heat conductivity	Km	0.104E+00	BTU-in/hr/in**2/F
Heat capacity	Cm	0.250E+00	BTU/lb/F
Matrix tensile strength	SmT	0.710E+04	psi
Matrix compressive strength	SmC	0.140E+05	psi
Matrix shear strength	SmS	0.710E+04	psi
Allowable tensile strain	eps mT	0.200E-01	in/in
Allowable compr. strain	eps mC	0.500E-01	in/in
Allowable shear strain	eps mS	0.350E-01	in/in
Allowable torsional strain	eps mTOR	0.350E-01	in/in
Void heat conductivity	kv	0.225E+00	BTU-in/hr/in**2/F
Glass transition temperature	Tgdr	0.220E+03	F

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13. ABSTRACT ***(Maximum 200 words)***

The BLASIM computer code can analyze solid, hollow, composite and superhybrid blades. The solid blade is made up of a single material where hollow, composite and superhybrid blades are constructed with prescribed composite layup. The properties of a composite blade can be specified by inputting one of two options: (1) individual ply properties, or (2) fiber/matrix combinations. When the second option is selected, BLASIM utilizes ICAN (Integrated Composite ANalyzer) to generate the temperature/moisture dependent ply properties of the composite blade. Two types of geometry input can be given: airfoil coordinates or NASTRAN type finite element model. These features increase the flexibility of the program. The user's manual provides sample cases to facilitate efficient use of the code while gaining familiarity.

14. SUBJECT TERMS
Composite; Hybrid; Superhybrid; Solid blades; Hollow blades; Fibers; Matrix temperature; Moisture; Finite element; Interactive; Batch

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